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National Dioxin Study Tier 4 - Combustion Sources: Final Test Report - Site 11 Drum and Barrel Reclamation Furnace DBR-A

Radian Corp., Research Triangle Park, NC

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Final Test Report — Site 11 Drum and Barrel Reclamation Furnace DBR — A

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16. ABSTRACT

This report summarizes the results of a dioxin/furan emissions test of a drum and barrel reconditioning furnace equipped with an afterburner for emissions control. Steel drums are reconditioned by combusting the drum contents (residual material) in a tunnel furnace. The test was the 11th in a series of emission tests conducted under Tier 4 of the National Dioxin Study. The primary objective of Tier 4 is to determine if various combustion devices are sources of dioxin and/or furan emissions. If any of the combustion sources are found to emit dioxin or furan, the secondary objective of Tier 4 is to quantify these emissions.

Drum reconditioning furnaces are one of 8 combustion device categories that have been tested in the Tier 4 program. The tested furnace, hereafter referred to as furnace DBR-A, was selected for this test after an initial information screening and a one-day pretest survey. The drums which are processed at the plant are received from a number of different sources, thus the combustible material burned in the furnace is heterogeneous. Furnace DBR-A is considered representative of other drum reconditioning furnaces operating in the United States.

Data presented in the report include dioxin (tetra through octa homologue +2378 TCDD) and furan (tetra through octa homologue +2378 TCDF) results for both stack samples and ash samples. In addition, process data collected during sampling are also presented.

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FOREWORD

This report is the result of a cooperative effort between the Office of Research and Development's Hazardous Waste Engineering Research Laboratory (HWERL) and the Office of Air Quality Planning and Standard's Monitoring and Data Analysis Division (MDAD). The overall management of Tier 4 of the National Dioxin Study was the responsibility of MDAD. In addition, MDAD provided technical guidance for the source test covered by this report. HWERL was directly responsible for the management and technical direction of the source test.

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1.0 INTRODUCTION

This report summarizes the results of a dioxin/furan[a] emissions test of a drum and barrel reconditioning furnace equipped with an afterburner for emissions control. Steel drums are reconditioned by combusting the drum contents (residual material) in a tunnel furnace. The test was the eleventh in a series of emission tests conducted under Tier 4 of the National Dioxin Study. The primary objective of Tier 4 is to determine if various combustion devices are sources of dioxin and/or furan emissions. If any of the combustion sources are found to emit dioxin or furan, the secondary objective of Tier 4 is to quantify these emissions.

Drum reconditioning furnaces are one of eight combustion device categories that have been tested in the Tier 4 program. The tested furnace, hereafter referred to as furnace DBR-A, was selected for this test after an initial information screening and a one-day pretest survey. The drums which are processed at the plant are received from a number of different sources, thus the combustible material burned in the furnace is heterogeneous. Furnace DBR-A is considered representative of other drum reconditioning furnaces operating in the United States.

This test report is organized as follows. A summary of test results and conclusions is provided in Section 2, followed by a detailed process description in Section 3. The source sampling and analysis plan is outlined in Section 4 and the field sampling and analytical data are presented in Section 5. Sections 6 through 8 present various testing details. These include descriptions of the sampling locations and procedures (Section 6), descriptions of the analytical procedures (Section 7), and a summary of the quality assurance/quality control (QA/QC) results (Section 8). The appendices contain data generated during the field sampling and analytical activities.

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[a] The term "dioxin/furan" and the acronyms PCDD and PCDF as used in this report refer to the polychlorinated dibenzo-p-dioxin and dibenzofuran isomers with four or more chlorine atoms.

2.0 TEST PROGRAM SUMMARY

2.1 SOURCE SAMPLING AND ANALYSIS OVERVIEW

The host site for test number 11 of the Tier 4 dioxin emission test program is a steel drum reconditioning facility. This plant operates a burning furnace to prepare used steel drums for cleaning to base metal. The cleaned drums are repaired, repainted, relined and sold for reuse. The furnace is typical of the tunnel furnace design used in the drum reconditioning industry. The exhaust gases from the furnace flow to a natural gas-fired afterburner where combustion is completed. A simplified process flow diagram of the furnace/afterburner system is shown in Figure 2-1.

The gaseous and solid sampling conducted in this test program is summarized in Table 2-1. Sampling for dioxin emissions was performed at the afterburner outlet exhaust stack and incinerator outlet exhaust duct during each of three test runs conducted on August 6, 7, and 8, 1985. The dioxin/furan sampling procedure used was based upon the Modified Method 5 (MM5) procedure developed by the American Society of Mechanical Engineers (ASME) for measuring emissions of chlorinated organic compounds. Two modifications in the sampling procedure were necessary and are described in Section 6 of this report. The MM5 sample train components (filter, sorbent traps, probe rinses, etc.) were analyzed for dioxins by two of three EPA laboratories referred to collectively in this report as "Troika." The analyses performed by Troika quantified the 2378-tetrachlorodibenzo-p-dioxin (2378-TCCD) isomer, the tetra-through octa-polychlorinated dioxin homologues (PCDD), and the tetra-through octa-polychlorinated dibenzofuran (PCDF) homologues present in the samples.

Dioxin precursor analyses were performed on samples of the drum residues and coatings. The dioxin precursor analyses were performed by Radian. The specific dioxin precursors analyzed for were chlorophenols, chlorobenzenes, polychlorinated biphenyls (PCB), and total chlorine.

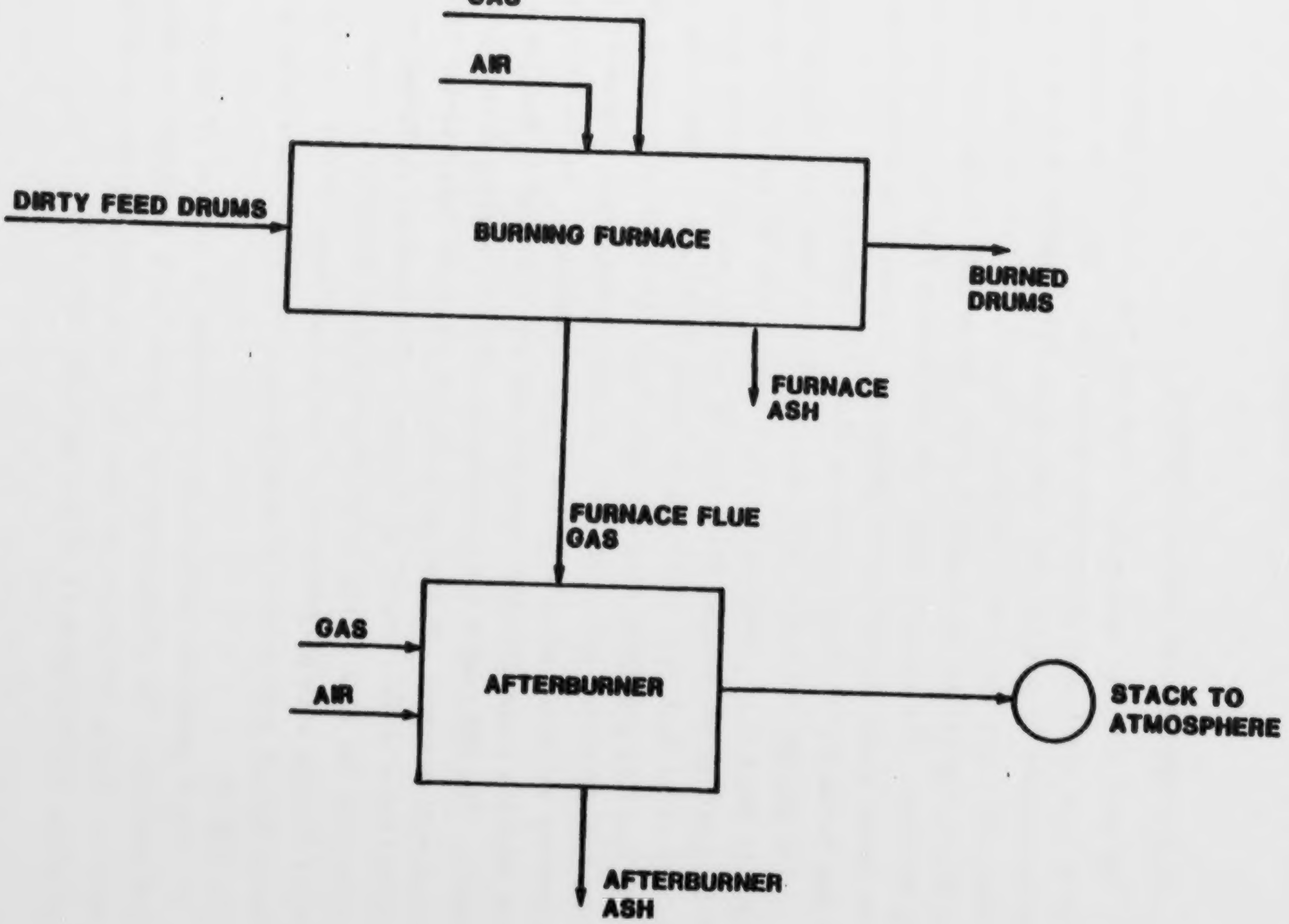

GAS
AIR
DIRTY FEED DRUMS
BURNING FURNACE
BURNED DRUMS
FURNACE ASH
FURNACE FLUE GAS
GAS
AIR
AFTERBURNER
STACK TO ATMOSPHERE
AFTERBURNER ASH

Figure 2-1. Simplified Flow Diagram of Furnace DBR-A.

TABLE 2-1. SOURCE SAMPLING AND ANALYSIS OVERVIEW FOR SITE DBR-A

Item	Description
1. Number of test runs	- Three identical test runs (Runs, 1, 2, 3).
2. Gaseous Sampling	- MM5 sampling at the afterburner inlet and exhaust stack. Dioxin/furan analysis (Runs 1, 2, 3).
	- HCl Train sampling at the afterburner exhaust stack. Total Cl analysis (Runs 1, 2, 3).
	- EPA Reference Methods 2 and 4 at the afterburner exhaust stack. Gas velocity and moisture (Runs 1, 2, 3).
	- EPA Method 3 integrated bag sampling at the after exhaust stack. Analysis for CO_2, O_2, and N_2 to compute gas molecular weight. (Runs 1, 2, 3).
	- Continuous monitoring of CO, CO_2, O_2, SO_2, NO_x, THC at afterburner exhaust stack (Runs 1, 2, 3).
	- Ambient air sampling near furnace/ afterburner (two identical composites for Runs 1, 2, 3). Dioxin/furan precursor analysis.
3. Solid Sampling	- Drum residues and coatings (Runs 1, 2, 3). Dioxin/furan precursor analysis.
	- Furnace ash. Inlet and outlet ash (Runs 1, 2, 3). Dioxin/furan analysis.
	- Soil sampling (One composite sample from 10 locations.) Potential dioxin/furan analysis.

Continuous emission monitoring (CEM) was performed by Radian at the afterburner outlet exhaust stack for CO, CO_2, SO_2, NO_x, total hydrocarbons (THC), and O_2. The continuous monitoring data were used in conjunction with process data to relate dioxin emissions to combustion conditions.

A single composite soil sample was taken by Radian and transferred to Tier 7 of the National Dioxin Study for possible dioxin/furan analysis. The soil sample results would provide information on the dioxin content of soils near the plant.

2.2 SUMMARY OF RESULTS

Figure 2-2 summarizes the data obtained at Site DBR-A during the Tier 4 test program. Detectable quantities of all targeted dioxin and furan species were found in the stack gas emissions at the afterburner outlet. As shown in Table 2-2, average as-measured stack gas concentrations of 2378-TCDD, total PCDD, and total PCDF were 0.022 ng/dscm, 2.1 ng/dscm, and 11.3 ng/dscm, respectively. This corresponded to hourly mass emission rates of approximately .25 ug/hr 2378-TCDD, .24 ug/hr total PCDD, and 130 ug/hr total PCDF. Total dioxin emissions were fairly evenly distributed among the tetra-through octa-chlorinated dioxin homologues, while the tetra- and penta-chlorinated furnace homologues were more prevalent than the hexa-through octa-chlorinated furan homologues.

Average as-measured concentrations at the inlet to the afterburner were 3.5 ng/dscm 2378-TCDD, 160 ng/dscm total PCDD, and 470 ng/dscm total PCDF. This corresponded to inlet mass flow rates of 25 ug/hr 2378 TCDD, 1050 ug/hr total PCDD, and 3110 ug/hr total PCDF. The distributions of the individual dioxin and furan homologues at the afterburner inlet were similar to that at the afterburner outlet. Comparison of the afterburner inlet and outlet dioxin/furan concentrations and emission rates indicated that the afterburner was very effective controlling dioxin/furan emissions.

Detectable quantities of all targeted dioxins and furans except 2378-TCDD were found in the ambient air samples taken near the exit of the furnace. The measured concentrations of total PCDD and total PCDF in the ambient air were 0.39 ng/dscm and 5.3 ng/dscm, respectively. Valid results were not obtained

Furnace Operating Data (D)

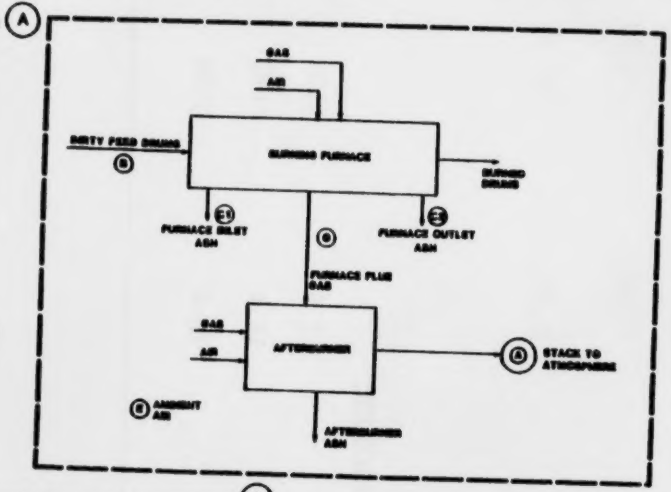
Drums/Hr	118
Firebox Temperature	588°C
Afterburner Temperature	827°C

Afterburner Outlet Chloride Emissions Data (A)

Emissions Type	Concentration mg/dscm	Emissions Rate kg/hr	Emission Factor mg/drum
Front Half	0.17	0.002	17
Back Half	39.2	0.47	3980
Train Total	39.3	0.47	4000

Continuous Monitoring Data (A)

O_2	13.5 vol %
CO_2	11.8 vol %
CO	234 ppmv
THC	5.6 ppmv
SO_2	18.9 ppmv
NO_x	132 ppmv


GAS
AIR
DIRTY FEED DRUMS
(B)
BURNING FURNACE
BURNED DRUMS
(C1)
FURNACE INLET ASH
(C2)
FURNACE OUTLET ASH
FURNACE FLUE GAS
GAS
AIR
AFTERBURNER
(A)
STACK TO ATMOSPHERE
(E)
AMBIENT AIR
AFTERBURNER ASH

Ambient Air Data (E)

Species	Concentration ng/dscm
2378 TCDD	ND
Total PCDD	.39
Total PCDF	5.32

Afterburner Outlet Flue Gas Parameter Data (A)

Flow Rate	193 dscmm
Temperature	684°C
Moisture	9.7%

Feed Precursor Data (B)

Drum Coating	
Chlorobenzenes	Not Detected
PCB's	Not Detected
Chlorophenols	Not Detected
TOX	Not Analyzed
Drum Residues	
Chlorobenzenes	Detected
PCB's	Not Detected
Chlorophenols	Not Detected
TOX	Detected
PCDD/PCDF	Trace

Afterburner Outlet Dioxin/Furan Emissions Data (A)

Species	As-measured Concentration ng/dscm	Emission Rate ug/hr	Emission Factor ug/drum
2378 TCDD	.022	0.25	0.002
Total PCDD	2.1	23.8	0.20
Total PCDF	11.3	129	1.10

Note: Emission factor expressed on per-drum-burned basis.

Ash Analysis (C1) (C2)

Species	Inlet Ash (ppb)[a]	Outlet Ash (ppb)[a]
2378-TCDD	ND	b
Total PCDD	10.8	1.0
Total PCDF	11.2	10.3

ND - not detected at 0.03 ppb detection limit.

[a] Average of valid test runs.

[b] Invalid analytical results.

Figure 2-2. Data summary for Site DBR-A.

TABLE 2-2. SUMMARY OF MEAN DIOXIN/FURAN EMISSIONS DATA FOR SITE DBR-A

PARAMETER	2378 TCDD	TOTAL PCDD	TOTAL PCDF
Afterburner Outlet Stack			
Emissions Concentration (ng/dscm)			
As-measured	0.022	2.10	11.3
Corrected to 3% O_2	0.052	4.98	27.0
Emissions Rate (ug/hr)	0.250	23.8	129
Afterburner Inlet Stack			
Emissions Concentration (ng/dscm)			
As-measured	3.5	158	466
Corrected to 3% O_2	16.4	687	2170
Emissions Rate (ug/hr)	25.0	1050	3110

for the dioxin/furan analyses of the furnace outlet ash samples because of inadequate GC/MS resolution and sensitivity for these samples. Analysis of furnace inlet ash samples, however, detected all the species analyzed for except the 2378-TCDD isomer and the penta-CDD homologue. Small quantities of chlorobenzenes were detected in the drum residues (33 ppm), but polychlorinated biphenyls and chlorophenols were not detected. Total organic halide (TOX) analysis of a composite sample of drum residues indicated potential for the presence of significant quantities of TOX in the furnace feed. Dioxin/furan analyses of drum residues from Runs 01 and 02 detected small amounts of hexa-CDD, hepta-CDD, and octa-CDD homologues as well as small amounts of TCDF, hepta-CDF, and octa-CDF. According to plant personnel, the drum furnace and afterburner were operated under conditions representative of normal operation during the sampling periods. There were no unusual process upsets in the furnace or afterburner operation during the test periods. Drum feed rates during the test periods averaged 118 drums/hr. The furnace temperature averaged 588^{o}C (1090^{o}F), and the afterburner temperature averaged 827^{o}C (1521^{o}F).

Average flue gas concentrations measured in the exhaust stack breeching by the Radian continuous emissions monitoring system were O_2, 13.5 vol %; CO_2, 11.8 vol %; CO, 234 ppmv; THC, 5.6 ppmv as propane; SO_2 18.9 ppmv; and NO_x, 132 ppmv. Total chloride emissions concentrations measured using the HCl train at the exhaust gas stack were 39 mg/dscm (as-measured), and the total HCl emission rate was 472 g/hr.

The composite soil sample obtained at Site DBR-A has been archived by Radian/RTP.

3.0 PROCESS DESCRIPTION

This section describes the host site and the drum burning furnace/afterburner system tested. Data summarizing the operation of the furnace/afterburner system during the test periods are presented in Section 5.0.

3.1 HOST SITE DESCRIPTION

The host site is a typical steel drum reconditioning facility that uses the burning process to aid in cleaning used drums. This facility operates one drum burning furnace which typically processes about 1000 open-top drums per day.

3.2 BURNING PROCESS AND FURNACE DESCRIPTION

The drum burning process used at site DBR-A is believed to be a typical example of the drum reclaiming industry. The drum burning process subjects used drums to an elevated temperature in a tunnel furnace for a sufficient time so that the paint, interior linings, and residues of previous contents are burned or charred so that subsequent shotblasting will clean the drum to bare metal. The process is shown schematically in Figure 3-1.

The burning furnace at Site DBR-A is an ECO Model 100 that was installed in 1974. The furnace is equipped with 12 natural gas-fired burners, with six burners on each side of the furnace. The maximum heat input capacity is 6.25 million Btu/hr, but the furnace typically operates with about 4 million Btu/hr heat input. The primary chamber temperature is maintained at about 1000°F. The dirty drums are loaded onto a conveyor that moves at a fixed speed. Before entering the furnace, any free contents in the drums are drained into collection barrels. As the drums pass through the preheat and ignition zone of the furnace, additional contents of the drums drain into the furnace ash trough. A drag conveyor moves these sludges and ashes through the furnace to a collection pit. The drums are air cooled as they exit the furnace.

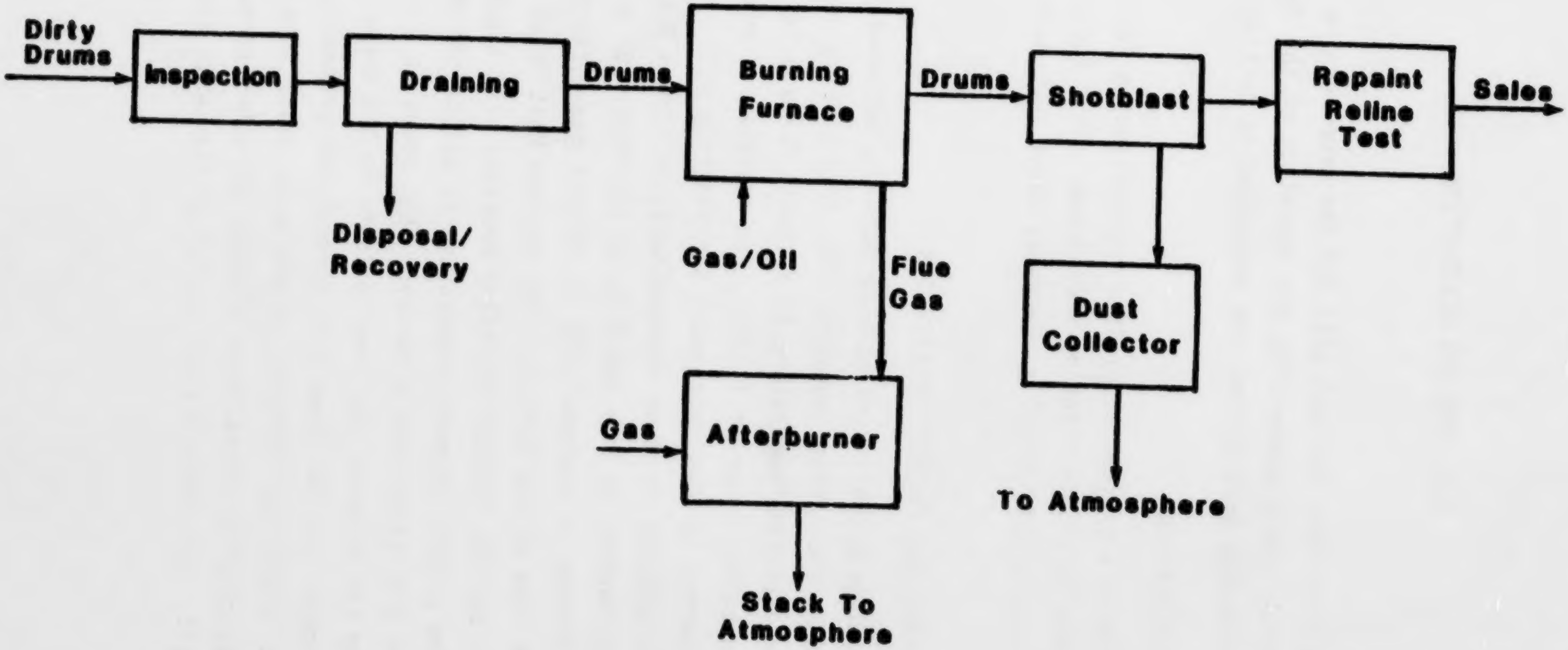

Dirty
Drums
Inspection
Draining
Disposal/
Recovery
Drums
Burning
Furnace
Gas/Oil
Flue
Gas
Gas
Afterburner
Stack To
Atmosphere
Drums
Shotblast
Dust
Collector
To Atmosphere
Repaint
Reline
Test
Sales

Figure 3-1. Burning Process Schematic Flow

3.3 DRUM CONTENTS

The drums processed at the facility come from a variety of sources. During the testing periods, two different types of drums were processed. The first type, burned during the first half of each test run, were tight head drums with the tops removed. These drums contained mainly lacquer and organic solvents. The second type, burned during the second half of each test run, were open-head drums containing inks, enamel-type paints, and other material. Plant personnel indicated that no herbicide product drums were processed here; however, some herbicide product drums were observed being processed during the testing period. In addition, empty drums on site were observed to have hazardous waste labels. The facility does not accept drums for processing that contain more residues than allowed by RCRA regulations (i.e., more than one inch of material remaining in the bottom of the drum). A listing of the labeled contents in each of the drums is contained in Appendix B.

3.4 AFTERBURNER DESCRIPTION

Exhaust gases from the burning furnace are drawn through a breeching and fan to the afterburner. The afterburner is fitted with two natural gas-fired burners with a total heat rating of 3.38 million Btu/hr. The afterburner temperature is set at 1450^{o}F, but occasionally operates at 1500^{o} to 1600^{o}F. Gases leaving the afterburner flow through a refractory-lined stack to the atmosphere.

4.0 TEST DESCRIPTION

This section summarizes the field sampling and analytical measurements that were performed at Site DBR-A. The purpose of this section is to provide sufficient descriptive information about the test so that the test data presented in Section 5.0 can be easily understood. Specific testing details such as specific sampling locations and procedures are presented in Section 6.0.

This section is divided into two parts. Section 4.1 summarizes field sampling activities and Section 4.3 summarizes analytical activities performed during the test program.

4.1 FIELD SAMPLING

Table 4-1 shows the source sampling and analysis matrix for Site 11. Three dioxin/furan emissions test (Runs 01, 02, 03) were performed at the afterburner outlet exhaust stack and incinerator outlet exhaust duct. These sampling locations are shown as points A and G in Figure 4-1, respectively. Also, ambient air sampling for dioxin/furans was performed in the near vicinity of the incinerator exit. The sampler was located within the visible plume of the incinerator which made this more of a process fugitive sample than an ambient air sample. Dioxin/furan sampling in general followed the Modified Method 5 (MM5) sampling protocol developed by the American Society of Mechanical Engineers (ASME) for measuring emissions of chlorinated organic compounds. Two modifications of the sampling protocol that were adopted are described in Section 6. During each test run, at least 240 minutes of on-line sampling were performed with the MM5 trains.

Concentrations of HCl in the flue gas were determined for each test day at the afterburner outlet exhaust stack using another modification of EPA Method 5 (MM5/HCl). Continuous emission monitoring (CEM) of O_2, CO, CO_2, NO_x, and total hydrocarbons (THC) was performed at the afterburner outlet during each of the test runs.

Revised
7/25/85

TABLE 4-1. SOURCE SAMPLING AND ANALYSIS MATRIX FOR SITE DBR-A

Sample Location Description	Location Identification[a]	Sample Type	Number of Samples	Distributing of Samples[b,c]	Analysis[d,e,f]	Dioxin Analysis Priority
Gaseous Samples						
1. Afterburner exhaust stack	A	MM5 Dioxin	3 sets of 6	3 sets to Troika	dioxin, furan	1
		MM5 Dioxin field recovery blank	1 set of 6	1 set to Troika	dioxin, furan	1
		HCl	3 sets of 3	3 sets to Radian	HCl	-
		HCl blank	1 set of 3	1 set to Radian	HCl	-
		EPA Method 2,4	3 sets	field analysis	gas flow, $\%H_2O$	-
		EPA Method 3	3 sets	field analysis	N_2, CO_2, O_2	-
		Continuous monitoring	3 sets	---	O_2, CO_2, CO, THC, SO_2, NO_x	-
2. Furnace exhaust duct	G	Single Point MM5	3 sets of 6	3 sets to Troika	dioxin/ furan	1
3. Ambient air	E	Ambient XAD	2 sets	1 set to Troika 1 set to Radian	dioxin/furan dioxin precursors	1 -
4. Laboratory blanks	-	MM5 laboratory proof blank	1 set of 3	1 set to Troika	dioxin/furan	1
		MM5 reagent blanks	1 set of 3	1 set to Troika	dioxin/furan	1
Solid Samples						
5. Drum residues	B	One composite per run from a systematic drum sampling scheme	1 set of 3	1 set to Troika	dioxin/furan	2 s
			1 set of 3	1 set to Radian	dioxin precursors	-
		One composite per run	1 set of 3	1 set to Radian	total chlorine	-

TABLE 4-1. SOURCE SAMPLING AND ANALYSIS MATRIX FOR SITE DBR-A

Sample Location Description	Location Identification[a]	Sample Type	Number of Samples	Distributing of Samples[b,c]	Analysis[d,e,f]	Dioxin Analysis Priority
6. Drum coatings		One grab sample of of paint and lining per entire test	3 sets of 1	1 set to Troika 1 set to Radian 1 set to Radian	dioxin/furan dioxin precursor total chlorine	2
7. Furnace Inlet ash	C1	One 500 gm composite per run	1 set of 3	1 set to Troika	dioxin/furan	
		One 5-lb composite per entire test	1 set of 1	1 set to EPA/Duluth	bioassay	
8. Furnace Outlet ash	C2	One 500 gm composite per run	1 set of 3	1 set to Troika	dioxin/furan	1
		One 5-lb composite per entire test	1 set of 1	1 set to EPA/Duluth	bioassay	
9. Soils	F	One composite of 10 grab samples	1 set of 1	1 set to Troika	dioxin/furan	3

[a] Location identifications as shown in Figure 4-1.

[b] Troika refers to the ERL-Duluth, ECL-Bay St. Louis, and EMSL-Research Triangle Park EPA laboratories as a collective unit.

[c] Radian refers to Radian's laboratory in Research Triangle Park, N.C.

[d] Dioxin means that 2,3,7,8-TCDD and tetra- through octa-dioxin homologue analyses will be performed.

[e] Dioxin precursors means that Cl-phenols, Cl-benzenes, PCB, and total chlorine analyses will be performed.

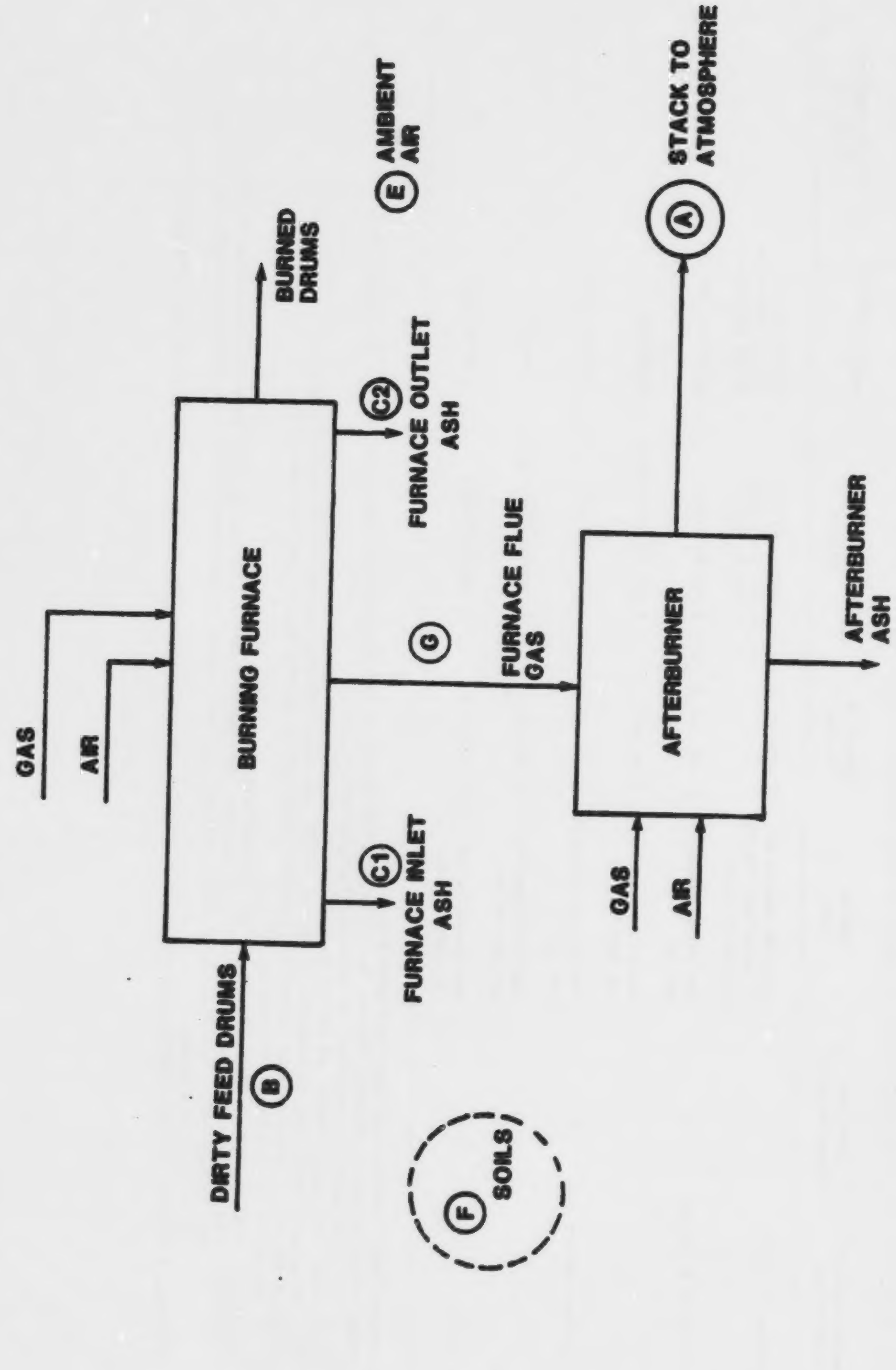
[f] Archive means that samples will be stored for possible future dioxin and/or dioxin precursor analyses.

[g] Dioxin analytical priorities are defined as follows:

Priority 1 - samples require immediate extraction and analysis.

Priority 2 - samples require immediate extraction if aqueous (designated "aq") but do not require immediate extraction if solid (designated "s"). All Priority 2 sample extracts and unextracted samples will be held for analysis pending the results of the Priority 1 analyses.

Priority 3 - samples will be archived for potential extraction and analysis pending the results of the Priority 2 analyses.


DIRTY FEED DRUMS
B
F
SOILS
GAS
AIR
BURNING FURNACE
C1
FURNACE INLET ASH
C2
FURNACE OUTLET ASH
BURNED DRUMS
E
AMBIENT AIR
G
FURNACE FLUE GAS
GAS
AIR
AFTERBURNER
AFTERBURNER ASH
A
STACK TO ATMOSPHERE

Three types of process samples were taken during the MM5 test periods: feed samples, inlet bottom ash and outlet bottom ash. Samples of the feed were obtained by taking a ladle full of material from every tenth drum fed to the furnace and compositing this in a steel container. Bottom ash samples were collected at the furnace inlet and outlet each hour. These samples were composited separately.

Soil samples were collected from ten locations at the plant site. The ten samples were combined into a single composite, which has been archived by Radian/RTP.

4.2 PROCESS DATA COLLECTION

Process data were collected to characterize the operation of the drum reconditioning furnace and the afterburner during the MM5 test periods. Table 4-2 shows the type of data that were collected during the sampling.

4.3 LABORATORY ANALYSES

Laboratory analyses performed on samples from Site DBR-A included dioxin/furan analyses, dioxin/furan precursor analyses, and total chloride analyses. These analyses are discussed in Sections 4.3.1, 4.3.2, and 4.3.3, respectively.

4.3.1 Dioxin/Furan Analyses

All dioxin/furan analyses for Site DBR-A samples were performed by two of three EPA laboratories collectively referred to as Troika. The two Troika laboratories are ECL-Bay St. Louis and EMSL-Research Triangle Park.

Field samples requiring dioxin/furan analysis were prioritized based on their relative importance to the Tier 4 program objectives. The priority levels, in order of decreasing importance, were designated Priority 1 through Priority 3.

Priority 1 samples were sent to Troika with instructions to perform immediate extraction and analysis. These included the MM5 train components, the MM5 field train blanks, ambient air samples, field solvent blanks, and the furnace outlet bottom ash samples.

Priority 2 samples were sent to Radian/RTP for archiving. These samples may be analyzed for dioxin/furan in the future, pending the results of the

TABLE 4-2. PROCESS MONITORING DATA OBTAINED AT SITE DBR-A

Parameter	Frequency of Data	Collection Procedure
Feed Data		
Total Drums Burned	Per test run, per test day	Observation/stopwatch Plant record
Drum Source and Contents	Per test run	Plant records and observations
Temperatures		
Primary Chamber	Each 30 minutes	Thermocouple
Afterburner	Each 30 minutes	Thermocouple
Miscellaneous		
Drum Conveyor Speed	Each test run	Plant record
Number of Burners in Use	Each test run	Observation
Natural Gas Used	Each test run	Plant meter

Priority 1 analyses. Priority 2 samples at Site DBR-A include the feed samples and drum coating samples.

The only Priority 3 sample taken was the composite soil sample. The soil sample is also being held by Radian/RTP pending evaluation of the Priority 1 and 2 analyses.

4.3.2 Dioxin/Furan Precursor Analyses

Dioxin/furan precursor analyses of furnace feed samples were performed by Radian/RTP. The specific dioxin/furan precursors analyzed for included chlorophenols, chlorobenzenes, PCB's and total chlorine.

4.3.3 Total Chloride Analysis

Total chloride analysis was performed on front-half and back-half HCl train samples. Also analyzed for total chlorides were the drum residues and drum coatings samples.

5.0 TEST RESULTS

The results of the Tier 4 dioxin/furan emissions test of Incinerator DBR-A are presented in this section. The daily individual test runs are designated as Runs 01 through 03.

Process data obtained during the test runs are presented in Section 5.1, and flue gas parameter data are presented in Section 5.2. The continuous emission monitoring results for O_2, CO, CO_2, NO_x, SO_2, and THC are presented in Section 5.3. The dioxin/furan emissions data for the MM5 sampling are contained in Section 5.4. Results of the HCl train sampling at the afterburner outlet exhaust stack are presented in Section 5.5. Dioxin/furan precursor analysis data for the drum residues and drum coating samples are presented in Section 5.6. The results of the dioxin/furan analyses of the furnace ash samples and ambient XAD train samples are presented in Sections 5.7 and 5.8, respectively.

5.1 PROCESS DATA

Process data were obtained to document Incinerator DBR-A and afterburner operation during the test runs. In general, the process data indicate that process operations were stable during each of the three test runs. Also, the process data indicate that process operations were similar for each test run. Thus, between-run comparisons are reasonable.

Mean values for the incinerator and afterburner operating parameters for the three test runs are shown in Table 5-1. The mean values for the three test runs are also averaged for a mean value for the entire three day test period. The individual data points are contained in Appendix B.

The average incinerator firebox temperature was 588°C (1,090°F) during the three day test period; the firebox temperature generally averaged about 538°C (1,000°F). The daily averages varied about 6 percent from the test period average. Thus, the incinerator was operating at a typical firebox temperature.

Table 5-1. Incinerator DBR-A Operating Data

Parameter	Run 1	Run 2	Run 3	Average
Incinerator Temperature (^oF)	1150	1030	1080	1090
Afterburner Temperature (^oF)	1560	1480	1530	1520
Afterburner Firing Rate (MMBTU/hr)[a]	6.6	7.2	6.8	6.9
Drum Feed Rate (Drums/hr)	115	110	130	118

[a] Based on a natural gas heat content of 1,000 BTU/scf, and differences between meter readings.

According to plant personnel, the afterburner generally operates from 760 to 871^{o}C (1,400 to 1,600^{o}F). During the three day test period, the average afterburner temperature was 827^{o}C (1,520^{o}F). The daily averages varied about 3 percent from the test period average. Thus, the afterburner was operating at a typical temperature.

The natural gas firing rate of the afterburner was calculated from the gas meter readings. During the three day test period, the average afterburner firing rate was 6.9 million Btu/hr. However, this firing rate is twice the design capacities of the burners and may be overstated. The natural gas firing rate for the afterburner was not directly measured but was derived from differences between meter readings.

The drums were fed to the incinerator at an average rate of 120 drums/hr during the three day test period. The daily drum feed rate varied about 8 percent from the test period average. The incinerator typically processes about 1,000 drums over an eight-hour period.

5.2 FLUE GAS PARAMETER DATA

5.2.1 Afterburner Inlet Location

Table 5-2 summarizes flue gas temperature, moisture, volumetric flow rate, and oxygen concentration data measured at the afterburner inlet location at Site DBR-A. These parameters were consistent between test runs. The average flue gas temperature and moisture content measured at the afterburner inlet location were 683^{o}C (1261^{o}F) and 10.7 vol% respectively. The average gas flow rate under actual stack temperature and moisture conditions was 429 acmm (15,100 acfm), and the average dry, standard flow rate was 115 dscmm (4,060 dscfm). Standard EPA conditions are 20^{o}C (68^{o}F) and 1 atm.

Flue gas oxygen concentration data at the afterburner inlet were obtained using integrated bag samples (EPA Method 3). The average measured O_2 concentration at this location was 17.2 vol%. The Method 3 data are used in subsequent sections of this report when normalizing as-measured afterburner inlet gas concentration of other species (e.g., dioxin, furan, CO, THC, etc.) to a reference oxygen level.

TABLE 5-2. FLUE GAS PARAMETERS AT SITE DBR-A[a] (AFTERBURNER INLET LOCATION)

Flue Gas Parameters	Run 01	Run 02	Run 03	Average
Temperature (°C)	712	634	702	683
Moisture (vol. %)	11.2	9.3	11.6	10.7
Volumetric Flow Rate				
Actual (acmm)	433	451	404	429
Dry Standard (dscmm)	112	129	105	115
Oxygen Content (vol. %)				
EPA Method 3	15.9	18.0	17.6	17.2

[a] Metric units are reported for all flue gas measurement data.
To convert to alternate units: °F = 1.8 x °C + 32
cfm = cmm x 35.3

5.2.2 Afterburner Outlet Location

Table 5-3 summarizes flue gas temperature, moisture, volumetric flow rate, and oxygen concentration data measured at the afterburner outlet stack at Site DBR-A. These parameters were consistent between test runs. The average flue gas temperature and moisture content measured at the exhaust stack location were 684°C (1263°F) and 9.7 vol %, respectively. The average exhaust gas flow rate under actual stack temperature and moisture conditions was 712 acmm (25,100 acfm), and the average dry, standard flow rate was 193 dscmm (6,800 dscfm). Standard EPA conditions are 20°C (68°F) and 1 atm.

Flue gas oxygen concentration data at the afterburner outlet were obtained from the Radian CEM system. The average O_2 concentrations of the flue gas was 13.5 vol%. The Radian CEM data will be used in subsequent sections of this report when normalizing as-measured afterburner outlet exhaust gas concentrations of other species (e.g., dioxin, furan, CO, THC, etc.) to a reference oxygen level.

5.3 CONTINUOUS EMISSIONS MONITORING DATA

Mean values and standard deviations of the continuously monitored combustion gases at the afterburner outlet location (O_2, CO, CO_2, SO_2, NO_x, and THC) are shown for each test run in Table 5-4. The overall mean values for the three test runs are as follows: oxygen, 13.5 percent by volume (dry); carbon monoxide, 234 ppmv (dry at 3 percent O_2); carbon dioxide, 11.8 percent by volume (dry at 3 percent O_2); nitrogen oxides, 132.0 ppmv (dry at 3 percent O_2; sulfur dioxide, 18.9 ppmv (dry at 3 percent O_2); and total hydrocarbons, 5.6 ppmv (wet at 3 percent O_2, as propane). The combustion gas results have been adjusted to 3 percent oxygen reference basis for comparison with other combustion sources in the Tier 4 program.

The mean oxygen, carbon dioxide, and nitrogen oxide concentrations showed little between-run variability. The maximum deviation between the mean concentration for any run and the overall mean value for all runs was less than 3 percent for these combustion gases. The mean carbon monoxide and sulfur dioxide concentrations showed some variability between runs with a maximum variability of less than 30 percent between the mean concentration for

TABLE 5-3. FLUE GAS PARAMETERS AT SITE DBR-A[a] (AFTERBURNER OUTLET LOCATION)

Flue Gas Parameters	Run 01	Run 02	Run 03	Average
Temperature (°C)	702	673	667	684
Moisture (vol. %)	9.0	9.5	10.5	9.7
Volumetric Flow Rate				
Actual (acmm)	672	718	747	712
Dry Standard (dscmm)	180	197	201	193
Oxygen Content (vol. %)				
Radian CEM	13.2	13.9	13.4	13.5

[a] Metric units are reported for all flue gas measurement data.
To convert to alternate units: °F = 1.8 x °C + 32
cfm = cmm x 35.3

TABLE 5-4. MEAN VALUES AND STANDARD DEVIATIONS OF CONTINUOUSLY MONITORED COMBUSTION GASES AT THE AFTERBURNER OUTLET EXHAUST STACK AT SITE DBR-A

Parameter[a]	Run 1	Run 2	Run 3	Average
O_2 (% vol)				
Mean	13.2	13.9	13.4	13.5
Standard Deviation	0.8	1.4	1.2	
CO (ppmv @ 3% O_2)				
Mean	262	266	175	234
Standard Deviation	137	210	143	
CO_2 (% vol @ 3% O_2)				
Mean	11.7	11.9	11.8	11.8
Standard Deviation	0.7	0.8	0.7	
SO_2 (ppmv @ 3% O_2)				
Mean	21.9	21.4	13.4	18.9
Standard Deviation	25.9	20.2	8.3	
NO_x (ppmv @ 3% O_2)				
Mean	133	131	131	132
Standard Deviation	26.1	31.6	39.0	
THC (ppmv @ 3% O_2)[b]				
Mean	2.4	7.5	6.8	5.6
Standard Deviation	1.3	14.1	18.4	

---

[a] All concentrations expressed on a dry volume basis except for total hydrocarbon concentrations, which are expressed on a wet volume basis.

[b] Total hydrocarbon data are expressed in units of ppmv (wet) as propane.

any run and the overall mean value for all runs. The total hydrocarbon concentrations had some variability, but were at low concentrations so that the variation was not significant. Also, the data did not show the expected positive relationship between carbon monoxide and total hydrocarbon concentrations.

Five-minute average values of the continuously monitored combustion gases are tabulated in Appendix C and are shown graphically as functions of time in Figures 5-1 through 5-6. Time periods for which data were not available due to instrument malfunctions are represented in Figures 5-1 through 5-6 by straight lines with no individual 5-minute data point symbols (e.g., Run 03 oxygen profile in Figure 5-1 from t = 2 hours to t= 4 hours).

5.4 DIOXIN/FURAN EMISSIONS DATA

As discussed in Section 4, dioxin/furan sampling was conducted at two locations at Site DBR-A, the afterburner inlet duct (drum furnace outlet duct) and the afterburner outlet stack. Emissions data for the afterburner inlet location and the afterburner outlet stack location are discussed in Section 5.4.1 and 5.4.2, respectively. The combined results are presented in Section 5.4.3.

5.4.1 Afterburner Inlet

Emissions concentration and emissions rate data measured at the afterburner inlet sampling location are shown in Tables 5-5 and 5-6 for the 2378-TCDD, total PCDD, and total PCDF species. The data include dioxin and furan captured by the entire MM5 train, including the filter, XAD sorbent trap, impingers and sample train clean-up rinses.

Average as-measured emissions concentrations of the 2378-TCDD, total PCDD and PCDF species were 3.5 ng/dscm 2378-TCDD, 158 ng/dscm total PCDD and 466 ng/dscm total PCDF. When corrected to 3% O_2 using the Radian CEM oxygen concentration data, these values correspond to 16.4 ng/dscm @ 3% O_2, 687 ng/dscm @ 3% O_2, and 2170 ng/dscm @ 3% O_2, respectively. Average emission rates for the three species were 24.2 ug/hr 2378-TCDD, 1050 ug/hr total PCDD, and 3110 ug/hr total PCDF. Emissions of 2378-TCDD, total PCDD, and total PCDF were fairly consistent between runs given the sampling and analysis

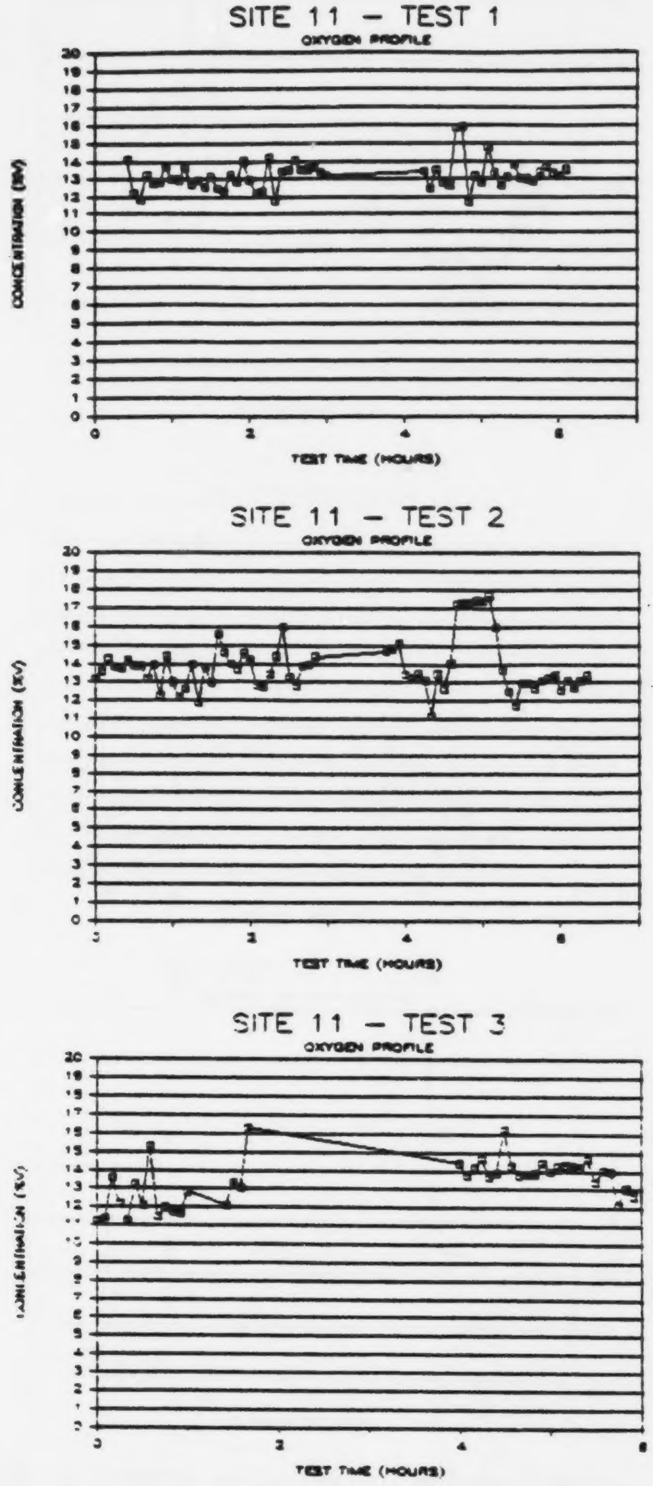


Figure 5-1. Oxygen Concentration History at Afterburner Outlet Exhaust Stack

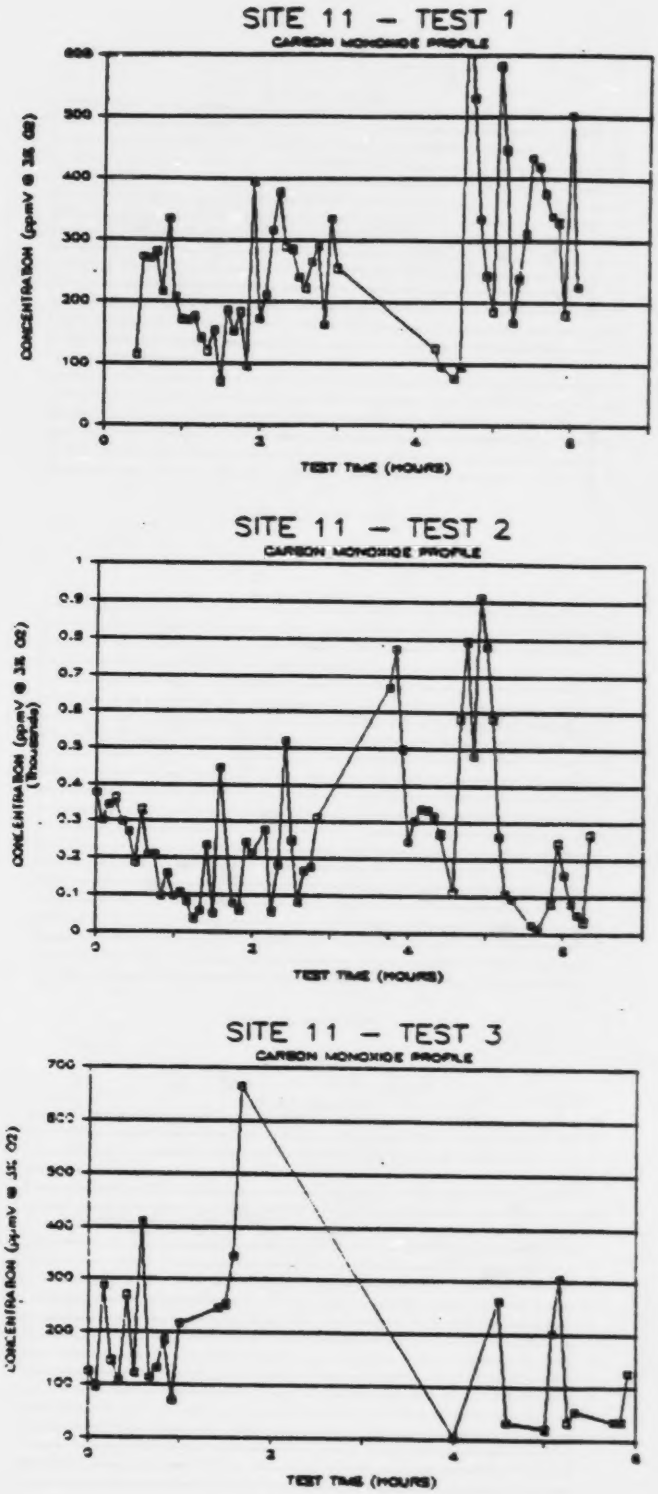
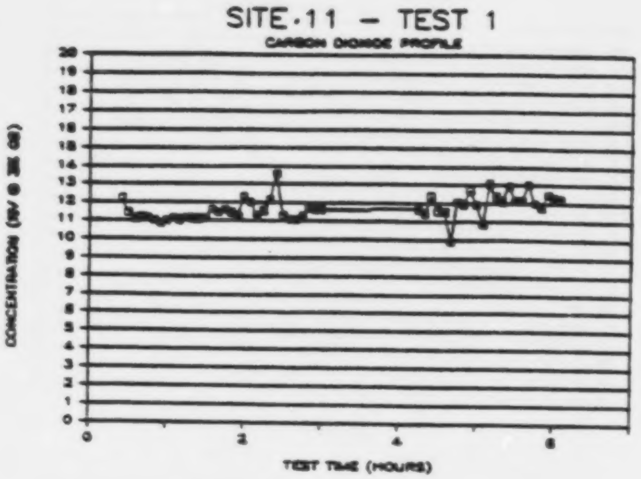
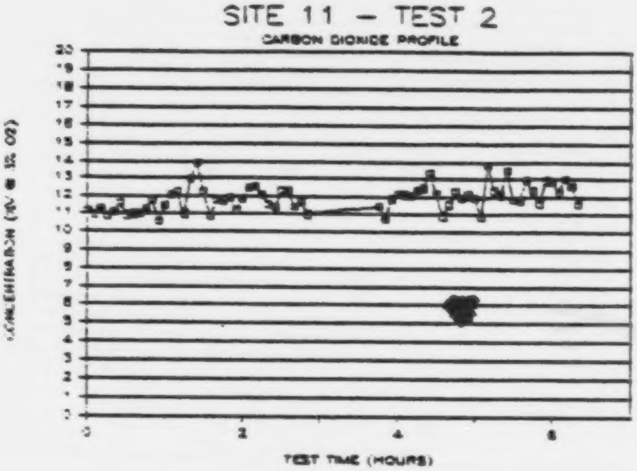


Figure 5-2. Carbon Monoxide Concentration History at Afterburner Outlet Exhaust Stack





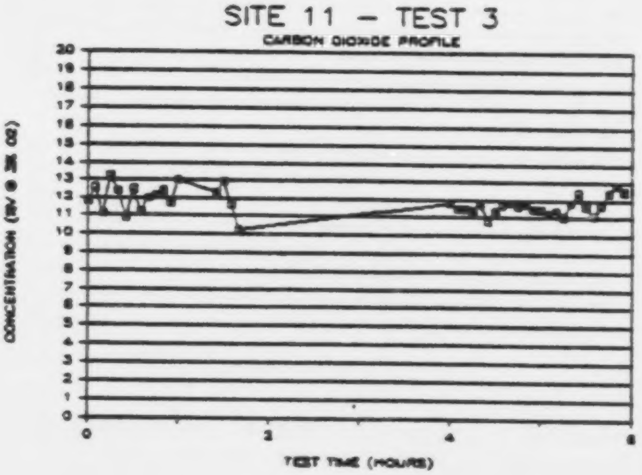


Figure 5-3. Carbon Dioxide Concentration History at Afterburner Outlet Exhaust Stack

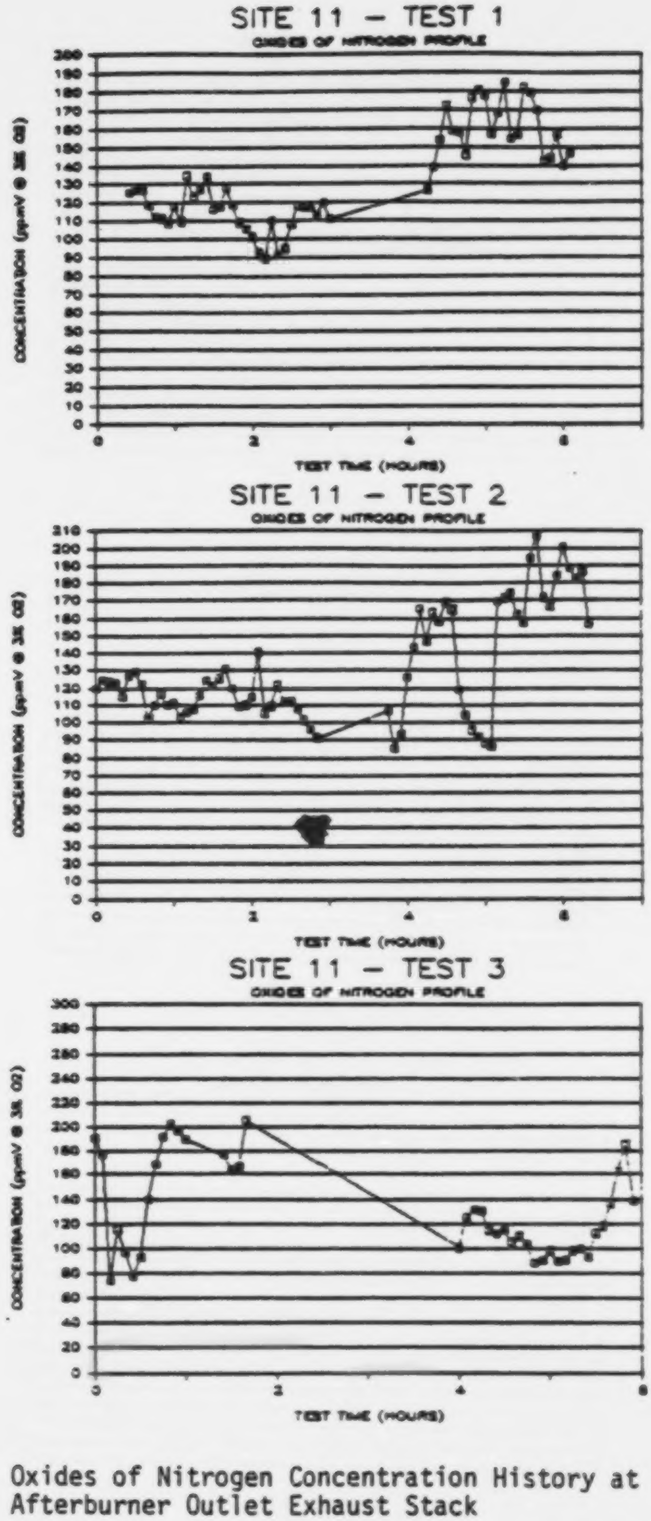


Figure 5-4. Oxides of Nitrogen Concentration History at Afterburner Outlet Exhaust Stack

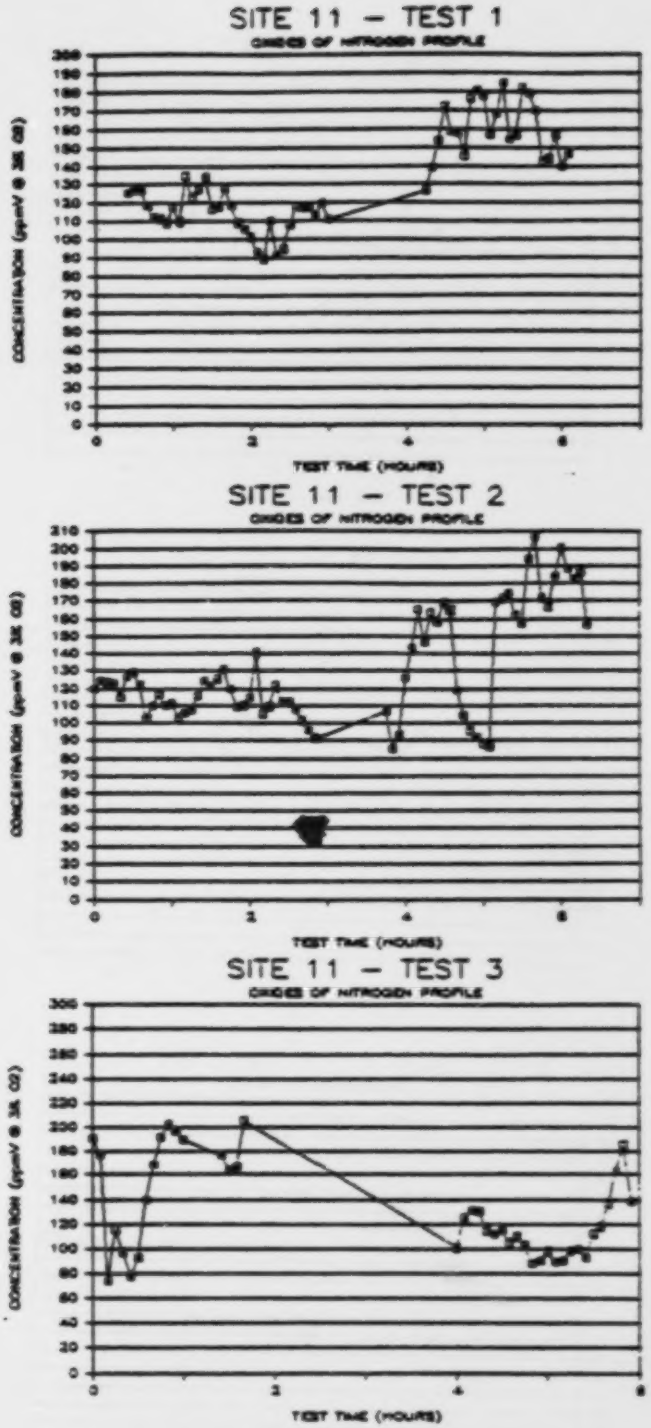
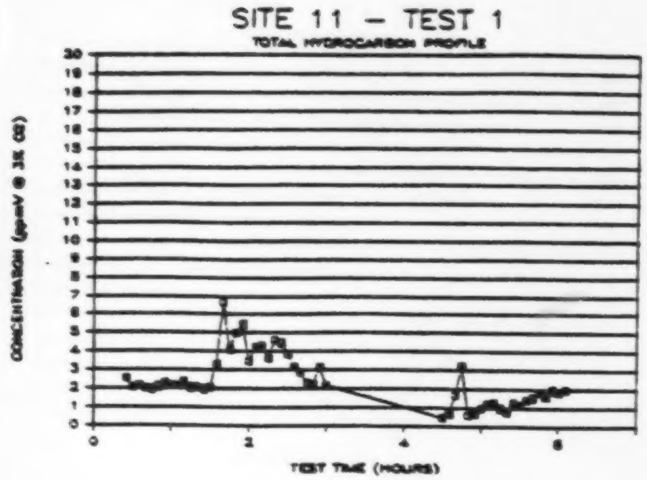
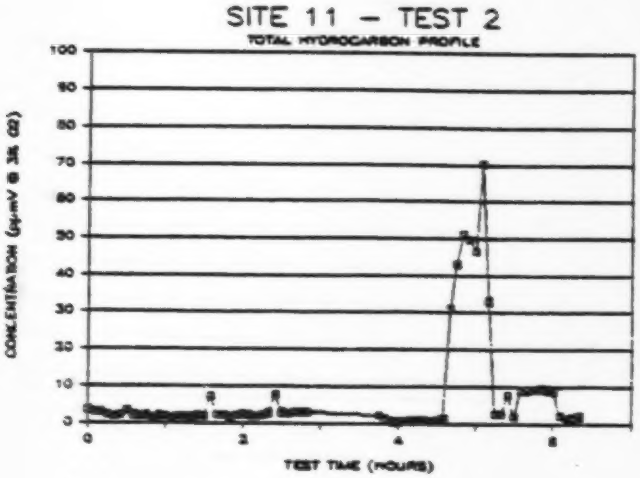


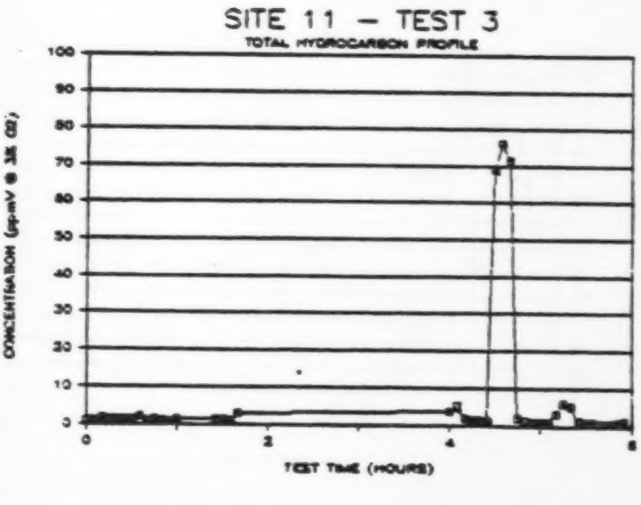
Figure 5-4. Oxides of Nitrogen Concentration History at Afterburner Outlet Exhaust Stack


SITE 11 – TEST 1

TOTAL HYDROCARBON PROFILE


SITE 11 – TEST 2

TOTAL HYDROCARBON PROFILE


SITE 11 – TEST 3

TOTAL HYDROCARBON PROFILE

Figure 5-5. Total Hydrocarbon History at Afterburner Outlet Exhaust Stack

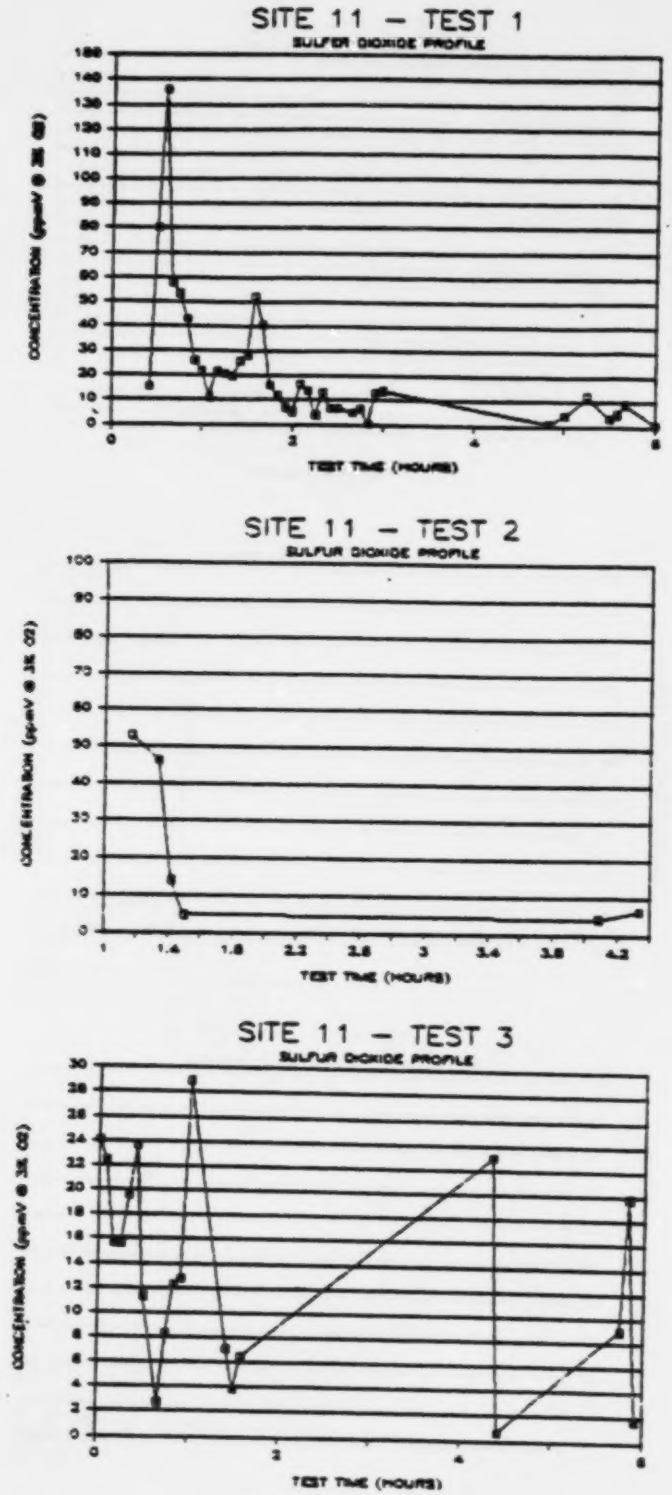


Figure 5-6. Sulfur Dioxide Concentration History at Afterburner Outlet Exhaust Stack

TABLE 5-5. OVERVIEW OF DIOXIN/FURAN CONCENTRATION DATA AT THE AFTERBURNER INLET FOR SITE DBR-A

Run Number	Emissions Concentration, ng/dscm 2378 TCDD	 Total PCDD	 Total PCDF
ng/dscm (as-measured)			
Run 01	5.0	269	595
Run 02	3.1	33	202
Run 03	2.5	173	602
Average	3.5	158	466
ng/dscm @ 3% O_2 [a]			
Run 01	17.6	949	2100
Run 02	18.4	199	1210
Run 03	13.2	914	3190
Average	16.4	687	2167

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[a] Flue gas concentration data corrected to 3% O_2 using the average Radian CEM data in Table 5-3.

TABLE 5-6. SUMMARY OF DIOXIN/FURAN DATA FOR THE AFTERBURNER INLET AT SITE DBR-A

Run Number	Dioxin/Furan Emission Rate, ug/hr		
	2378 TCDD	Total PCDD	Total PCDF
Run 01	33.4	1800	4000
Run 02	23.7	257	1560
Run 03	15.6	1080	3770
Average	24.2	1050	3110

variability. However, emissions from Run 02 were consistently lower than emissions from Run 01 or Run 03 for all species of concern except 2378-TCDD. The type of drums fed to the furnace generally included a combination of deheaded tight head drums and open head drums; however, Run 02 consisted almost entirely of open head drums.

Isomer- and homologue-specific emission concentration data are summarized in Table 5-7 and 5-8 for the three test runs. Run-specific data tables showing homologue emission concentrations in both ng/dscm and part-per-trillion units and homologue emission rates in ug/hr units are included in Appendix A. Detectable quantities of each targeted dioxin and furan species were found in the flue gas samples.

Figure 5-7 is a histogram that shows the relative distributions of the 2378-TCDD/TCDF isomers and the tetra- through octa-PCDD/PCDF homologues in the afterburner inlet flue gas stream (mole basis). The distribution of dioxin species was relatively uniform among the various homologues. The 2378-TCDD isomer accounted for 2 to 10 percent of the total dioxins analyzed for, which corresponded to roughly 11 to 23 percent of the tetra-homologue total for individual test runs. The contributions of the tetra- through octa-chlorinated dioxin homologues to the total PCDD emissions were tetra, 8 to 35 percent; penta, 11 to 28 percent; hexa, 10 to 30 percent; hepta, 6 to 51 percent; and octa, 4 to 18 percent. The furan species were less uniformly distributed than the dioxin species, with the tetra-chlorinated homologue being the largest single contributor to the total PCDF emissions. The contributions of the tetra- through octa-chlorinated furan homologues to the total PCDF were tetra, 40 to 51 percent; penta 27 to 29 percent; hexa 5 to 14 percent; hepta, 1 to 19 percent; and octa, 0.04 to 6 percent.

Emissions factors for the various dioxin and furan homologues were reasonably consistent between test runs. Emission factors based on the drum feed rates are shown in Table 5-9. Average emission factors for 2378-TCDD, total PCDD, and total PCDF were 0.2 ug 2378-TCDD emitted per drum; 8.8 ug total PCDD emitted per drum; and 26.0 ug total PCDF emitted per drum. The drum feed rate basis was chosen for the emission factors because the number and type of drums fed to the furnace determine the amount of waste material fed to the unit.

TABLE 5-7. SUMMARY OF DIOXIN/FURAN DATA AT THE AFTERBURNER INLET FOR SITE DBR-A (As-measured Concentrations)

Dioxin/Furan Isomer	Isomer Concentration in Flue Gas (ng/dscm)			
	Run 01	Run 02	Run 03	Avg.
DIOXINS				
2378 TCDD	4.98E+00	3.06E+00	2.49E+00	3.51E+00
Other TCDD	1.72E+01	1.05E+01	2.06E+01	1.61E+01
Penta-CDD	2.60E+01	9.15E+00	3.11E+01	2.21E+01
Hexa-CDD	2.53E+01	5.94E+00	5.36E+01	2.83E+01
Hepta-CDD	1.42E+02	2.47E+00	5.32E+01	6.60E+01
Octa-CDD	5.29E+01	2.07E+00	1.16E+01	2.22E+01
Total PCDD	2.69E+02	3.32E+01	1.73E+02	1.58E+02
FURANS				
2378 TCDF	1.44E+01	1.16E+01	1.26E+01	1.29E+01
Other TCDF	1.94E+02	1.15E+02	2.67E+02	1.92E+02
Penta-CDF	1.69E+02	5.86E+01	1.67E+02	1.31E+02
Hexa-CDF	4.34E+01	1.08E+01	9.15E+01	4.86E+01
Hepta-CDF	1.32E+02	4.49E+00	5.18E+01	6.28E+01
Octa-CDF	4.26E+01	1.04E+00	1.23E+01	1.86E+01
Total PCDF	5.95E+02	2.02E+02	6.02E+02	4.66E+02

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = not detected (detection limit in parentheses).
ng = 1.0E-09g

TABLE 5-8. SUMMARY OF DIOXIN/FURAN DATA AT THE AFTERBURNER INLET FOR SITE DBR-A
(Concentrations Corrected to 3 Percent Oxygen)

Dioxin/Furan Isomer	Isomer Concentration in Flue Gas (ng/dscm @ 3% oxygen) Run 01	Run 02	Run 03	Avg.
DIOXINS				
2378 TCDD	1.76E+01	1.84E+01	1.32E+01	1.64E+01
Other TCDD	6.07E+01	6.30E+01	1.09E+02	7.76E+01
Penta-CDD	9.19E+01	5.49E+01	1.65E+02	1.04E+02
Hexa-CDD	8.94E+01	3.57E+01	2.84E+02	1.36E+02
Hepta-CDD	5.03E+02	1.48E+01	2.81E+02	2.66E+02
Octa-CDD	1.87E+02	1.24E+01	6.15E+01	8.69E+01
Total PCDD	9.49E+02	1.99E+02	9.14E+02	6.87E+02
FURANS				
2378 TCDF	5.09E+01	6.98E+01	6.68E+01	6.25E+01
Other TCDF	6.85E+02	6.92E+02	1.41E+03	9.30E+02
Penta-CDF	5.95E+02	3.51E+02	8.84E+02	6.10E+02
Hexa-CDF	1.53E+02	6.47E+01	4.85E+02	2.34E+02
Hepta-CDF	4.66E+02	2.70E+01	2.74E+02	2.56E+02
Octa-CDF	1.50E+02	6.22E+00	6.49E+01	7.38E+01
Total PCDF	2.10E+03	1.21E+03	3.19E+03	2.17E+03

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
ng = 1.0E-09g

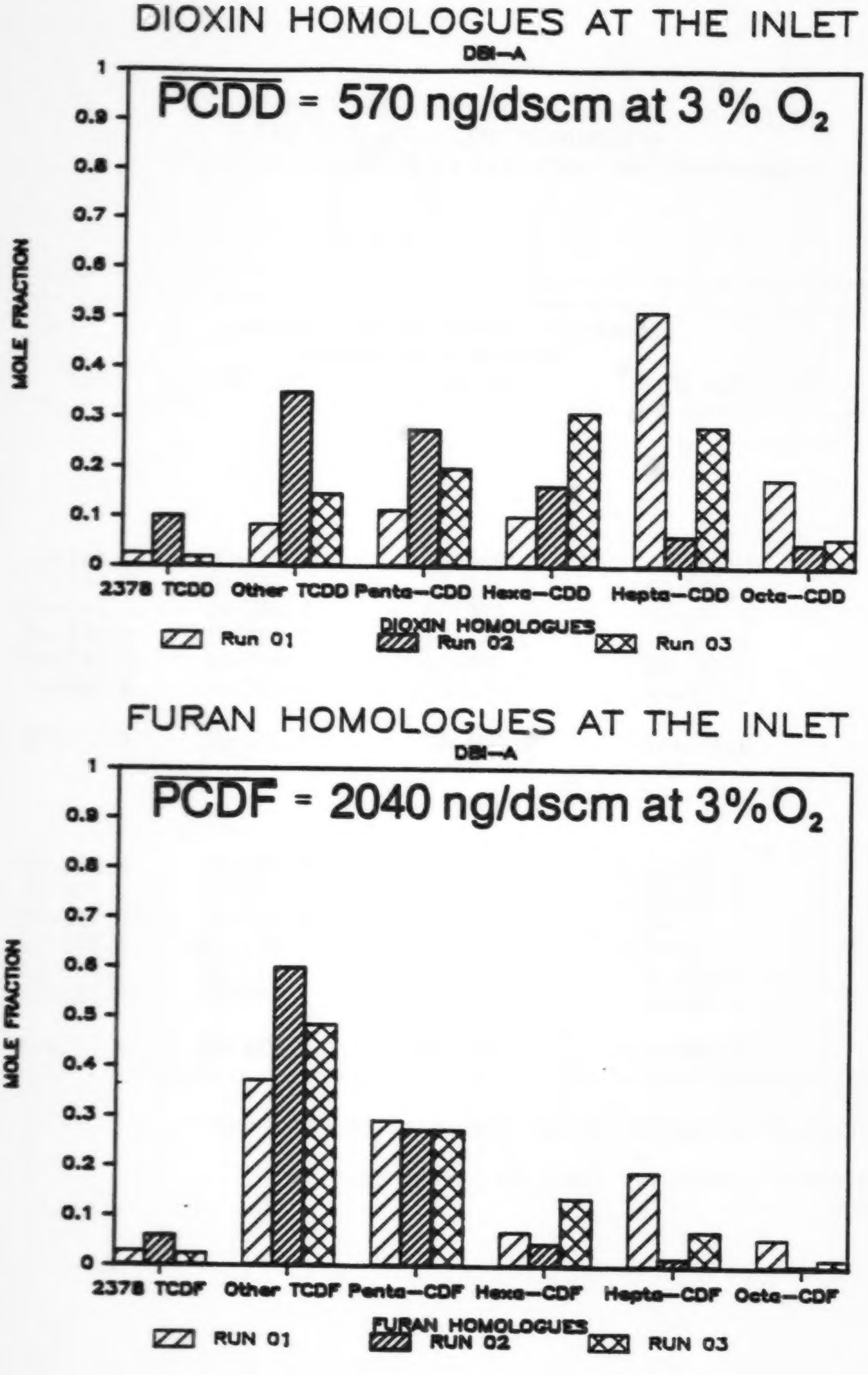

Figure 5-7. Dioxin/furan homologue distributions for the afterburner inlet stack emissions for Site DBR-A.

TABLE 5-9. DIOXIN/FURAN EMISSION FACTORS AT THE AFTERBURNER INLET FOR SITE DBR-A

Dioxin/Furan Isomer	Dioxin/Furan Emission Factors (ug/drum)			
	Run 01	Run 02	Run 03	Avg.
DIOXINS				
2378 TCDD	2.90E-01	2.15E-01	1.20E-01	2.09E-01
Other TCDD	1.00E+00	7.39E-01	9.92E-01	9.12E-01
Penta-CDD	1.52E+00	6.43E-01	1.50E+00	1.22E+00
Hexa-CDD	1.48E+00	4.18E-01	2.59E+00	1.49E+00
Hepta-CDD	8.31E+00	1.73E-01	2.56E+00	3.68E+00
Octa-CDD	3.09E+00	1.46E-01	5.61E-01	1.26E+00
Total PCDD	1.57E+01	2.33E+00	8.32E+00	8.78E+00
FURANS				
2378 TCDF	8.42E-01	8.18E-01	6.09E-01	7.56E-01
Other TCDF	1.13E+01	8.11E+00	1.29E+01	1.08E+01
Penta-CDF	9.85E+00	4.12E+00	8.06E+00	7.34E+00
Hexa-CDF	2.53E+00	7.58E-01	4.41E+00	2.57E+00
Hepta-CDF	7.71E+00	3.16E-01	2.50E+00	3.51E+00
Octa-CDF	2.48E+00	7.29E-02	5.91E-01	1.05E+00
Total PCDF	3.48E+01	1.42E+01	2.90E+01	2.60E+01

ug = 1.0E-06g

NOTE: Emission factors are expressed as ug emitted per drum fed to the furnace. Data are corrected to 3% O_2.

5.4.2 Afterburner Outlet Exhaust Stack

Emissions concentration and emissions rate data measured at the exhaust stack sampling location are shown in Table 5-10 and 5-11 for the 2378-TCDD isomer, total PCDD, and total PCDF species. The data include dioxin and furan captured by the entire MM5 train, including the filter, XAD sorbent trap, impingers and sample train clean-up rinses.

Average as-measured emissions concentrations of the 2378-TCDD, total PCDD and PCDF species were 0.022 ng/dscm 2378-TCDD, 2.10 ng/dscm total PCDD, and 11.3 ng/dscm total PCDF. When corrected to 3 percent O_2 using the Radian CEM oxygen concentration data, these values correspond to 0.052 ng/dscm @ 3% O_2, 4.98 ng/dscm @ 3% O_2, and 27.0 ng/dscm @ 3% O_2, respectively. Average emission rates for the three species were 0.250 ug/hr 2378-TCDD, 23.8 ug/hr total PCDD, and 129 ug/hr total PCDF. Emissions of 2378-TCDD, total PCDD, and total PCDF were fairly consistent between runs given the sampling and analysis variability. However, emissions from Run 01 were consistently higher than those from Runs 02 and 03 for all species of concern. During Run 01, stack and drum furnace temperatures were higher than during the other two runs. The drum feed rate was similar for all three runs. The type of drums fed to the furnace generally included a combination of deheaded tight head drums and open head drums. However, Run 02, which had the lowest 2378-TCDD and total PCDD emissions of the three runs, consisted almost entirely of open head drums.

Isomer- and homologue-specific emission concentration data for the afterburner outlet stack are summarized in Tables 5-12 and 5-13 for the three test runs. Run-specific data tables showing homologue emission concentrations in both ng/dscm and part-per-trillion units and homologue emission rates in ug/hr units are included in Appendix A. Detectable quantities of each targeted dioxin and furan species were found in the flue gas samples.

Figure 5-8 is a histogram that shows the relative distributions of the 2378-TCDD/TCDF isomers and the tetra- through octa-PCDD/PCDF homologues in the exhaust stack emissions (mole basis). The distribution of dioxin species was relatively uniform among the various homologues. The 2378-TCDD isomer accounted for 1 to 4 percent of the total dioxins analyzed for, which corresponded to roughly 10 to 20 percent of the tetra-homologue total for

TABLE 5-10. OVERVIEW OF DIOXIN/FURAN EMISSIONS CONCENTRATION DATA FOR SITE DBR-A (AFTERBURNER OUTLET LOCATION)

Run Number	Emissions Concentration, ng/dscm		
	2378 TCDD	Total PCDD	Total PCDF
ng/dscm (as-measured)			
Run 01	0.029	3.51	16.1
Run 02	0.011	1.24	9.6
Run 03	0.026	1.56	8.2
Average	0.022	2.10	11.3
ng/dscm @ 3% O_2[a]			
Run 01	0.066	8.11	37.3
Run 02	0.028	3.14	24.3
Run 03	0.061	3.69	19.4
Average	0.052	4.98	27.0

[a] Flue gas concentration data corrected to 3% O_2 using the average Radian CEM data in Table 5-4.

TABLE 5-11. SUMMARY OF DIOXIN/FURAN EMISSION RATE DATA FOR SITE DBR-A (AFTERBURNER OUTLET LOCATION)

Run Number	Dioxin/Furan Emission Rate, ug/hr 2378 TCDD	 Total PCDD	 Total PCDF
Run 01	0.309	38.0	174
Run 02	0.130	14.6	113
Run 03	0.311	18.8	98.8
Average	0.250	23.8	129

TABLE 5-12. SUMMARY OF DIOXIN/FURAN EMISSIONS DATA AT THE AFTERBURNER OUTLET STACK FOR SITE DBR-A (As-Measured Concentrations)

Dioxin/Furan Isomer	Isomer Concentration in Flue Gas (ng/dscm)			
	Run 01	Run 02	Run 03	Avg.
DIOXINS				
2378 TCDD	2.86E-02	1.10E-02	2.58E-02	2.18E-02
Other TCDD	6.86E-01	3.47E-01	4.64E-01	4.99E-01
Penta-CDD	6.29E-01	1.10E-01	1.80E-01	3.06E-01
Hexa-CDD	5.71E-01	1.65E-01	2.71E-01	3.36E-01
Hepta-CDD	1.03E+00	3.03E-01	3.35E-01	5.56E-01
Octa-CDD	5.71E-01	3.03E-01	2.84E-01	3.86E-01
Total PCDD	3.51E+00	1.24E+00	1.56E+00	2.10E+00
FURANS				
2378 TCDF	6.86E-01	2.20E-01	2.32E-01	3.79E-01
Other TCDF	7.23E+00	5.96E+00	4.74E+00	5.98E+00
Penta-CDF	4.26E+00	1.79E+00	1.79E+00	2.61E+00
Hexa-CDF	2.11E+00	8.82E-01	7.86E-01	1.26E+00
Hepta-CDF	1.46E+00	5.79E-01	5.15E-01	8.50E-01
Octa-CDF	4.00E-01	1.65E-01	1.29E-01	2.31E-01
Total PCDF	1.61E+01	9.60E+00	8.20E+00	1.13E+01

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = not detected (detection limit in parentheses).
ng = 1.0E-09g

TABLE 5-13. SUMMARY OF DIOXIN/FURAN EMISSIONS DATA AT THE AFTERBURNER OUTLET STACK FOR SITE DBR-A (Concentrations Corrected to 3 Percent Oxygen)

Dioxin/Furan Isomer	Isomer Concentration in Flue Gas (ng/dscm @ 3% oxygen)			
	Run 01	Run 02	Run 03	Avg.
DIOXINS				
2378 TCDD	6.59E-02	2.79E-02	6.10E-02	5.16E-02
Other TCDD	1.58E+00	8.80E-01	1.10E+00	1.19E+00
Penta-CDD	1.45E+00	2.79E-01	4.27E-01	7.19E-01
Hexa-CDD	1.32E+00	4.19E-01	6.41E-01	7.93E-01
Hepta-CDD	2.37E+00	7.68E-01	7.94E-01	1.31E+00
Octa-CDD	1.32E+00	7.68E-01	6.71E-01	9.19E-01
Total PCDD	8.11E+00	3.14E+00	3.69E+00	4.98E+00
FURANS				
2378 TCDF	1.58E+00	5.59E-01	5.49E-01	8.97E-01
Other TCDF	1.67E+01	1.51E+01	1.12E+01	1.43E+01
Penta-CDF	9.82E+00	4.54E+00	4.24E+00	6.20E+00
Hexa-CDF	4.88E+00	2.23E+00	1.86E+00	2.99E+00
Hepta-CDF	3.36E+00	1.47E+00	1.22E+00	2.02E+00
Octa-CDF	9.23E-01	4.19E-01	3.05E-01	5.49E-01
Total PCDF	3.73E+01	2.43E+01	1.94E+01	2.70E+01

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
ng = 1.0E-09g

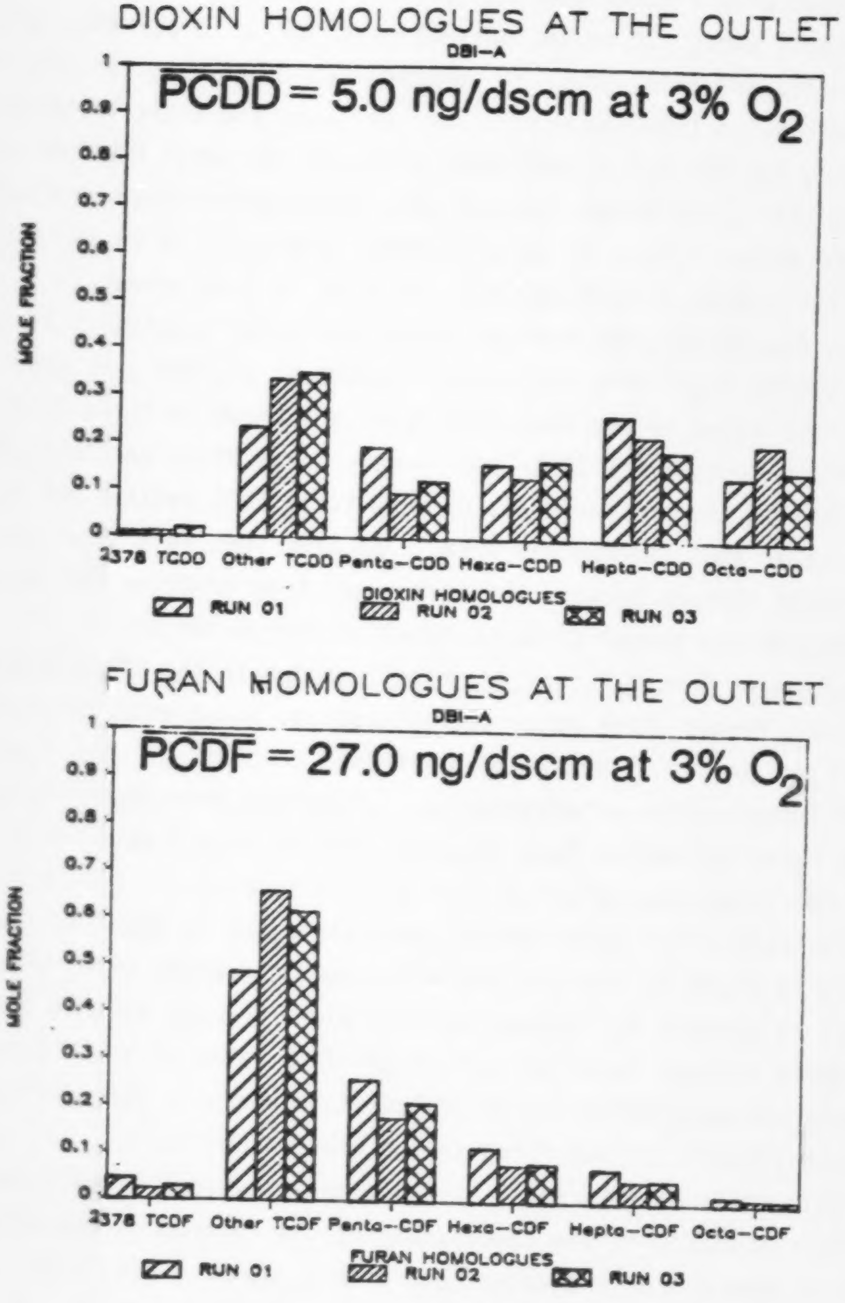

Figure 5-8. Dioxin/furan homologue distributions for the afterburner outlet stack emissions for Site DBR-A.

individual test runs. The contributions of the tetra- through octa-chlorinated dioxin homologues to the total PCDD emissions were: tetra, 13 to 16 percent; penta, 12 to 18 percent; hexa, 21 to 23 percent; hepta, 29 to 32 percent; and octa, 17 to 23 percent. The furan species were less uniformly distributed than the dioxin species, with the tetra-chlorinated homologue being the largest single contributor to the total PCDF emissions. The contributions of the tetra- through octa-chlorinated furan homologues to the total PCDF were: tetra, 45 to 52 percent; penta, 21 to 23 percent; hexa 7 to 13 percent; hepta, 5 to 9 percent; and octa, 4 to 6 percent.

Emission factors for the various dioxin and furan homologues at the afterburner outlet stack were reasonably consistent between test runs. Emission factors based on the drum feed rates are shown in Table 5-14. Average emission factors for 2378-TCDD isomer, total PCDD, and total PCDF were 0.002 ug 2378-TCDD emitted per drum; 0.20 ug total PCDD emitted per kg drum; and 1.10 ug total PCDF emitted per drum. The drum feed rate basis was chosen for the emission factors because the number and type of drums fed to the furnace determine the amount of waste material fed to the unit.

5.4.3 Reduction of Dioxin/Furan Concentrations Due to the Afterburner

The dioxin/furans which enter the afterburner along with the remaining hydrocarbons are partially destroyed by further combustion. The dioxin/furan removal efficiency of the afterburner was calculated from the difference between the inlet and outlet mass emission rate of each dioxin/furan homologue divided by the inlet mass emission rate of each homologue. Dioxin/furan removal efficiencies for other control devices tested in the Tier 4 program were calculated based on flue gas concentrations corrected to a reference oxygen level (3 percent O_2) because ambient air inleakage was the only reason for differences between inlet and outlet gas flow rates at these sites. However, only the mass emission rate calculation basis is appropriate for Site DBR-A because natural gas was fired in the control device.

Each mass emission rate value may have an analytical uncertainty of ± 50 percent. Analysis of the uncertainty of the control device efficiency (contained in Appendix I) indicates that with a measured efficiency of greater than 67 percent, the removal efficiency is most likely positive. With measured efficiencies between 67 percent and -200 percent, a definite

TABLE 5-14. DIOXIN/FURAN EMISSION FACTORS FROM THE AFTERBURNER STACK FOR SITE DBR-A

Dioxin/Furan Isomer	Dioxin/Furan Emission Factors (ug/drum)			
	Run 01	Run 02	Run 03	Avg.
DIOXINS				
2378 TCDD	2.68E-03	1.18E-03	2.39E-03	2.09E-03
Other TCDD	6.44E-02	3.72E-02	4.30E-02	4.82E-02
Penta-CDD	5.90E-02	1.18E-02	1.67E-02	2.92E-02
Hexa-CDD	5.37E-02	1.77E-02	2.51E-02	3.22E-02
Hepta-CDD	9.66E-02	3.25E-02	3.11E-02	5.34E-02
Octa-CDD	5.37E-02	3.25E-02	2.63E-02	3.75E-02
Total PCDD	3.30E-01	1.33E-01	1.45E-01	2.03E-01
FURANS				
2378 TCDF	6.44E-02	2.36E-02	2.15E-02	3.65E-02
Other TCDF	6.79E-01	6.40E-01	4.40E-01	5.86E-01
Penta-CDF	4.00E-01	1.92E-01	1.66E-01	2.53E-01
Hexa-CDF	1.99E-01	9.46E-02	7.29E-02	1.22E-01
Hepta-CDF	1.37E-01	6.21E-02	4.78E-02	8.22E-02
Octa-CDF	3.76E-02	1.77E-02	1.19E-02	2.24E-02
Total PCDF	1.52E+00	1.03E+00	7.60E-01	1.10E+00

ug = 1.0E-06g

NOTE: Emission factors are expressed as ug emitted per drum fed to the furnace.

conclusion cannot be drawn concerning the true removal efficiency, and below -200 percent the true removal efficiency is most likely negative.

The measured afterburner removal efficiencies for each dioxin/furan homologue at Site DBR-A are summarized in Table 5-15. The average removal efficiencies for all the homologues indicate positive true removal efficiency for the afterburner.

5.5 HCl TRAIN CHLORIDE EMISSIONS DATA

Table 5-15 summarizes HCl train chloride emissions data measured at the afterburner exhaust stack sampling location. The data are reported as "front-half," "back-half," and "train-total" chloride emissions. The front-half emissions represent chlorides captured in the probe rinse/filter fraction of the HCl train, which may include metal chlorides contained in the particulate matter. The back-half emissions represent chlorides captured in the HCl sample train impingers, which would include HCl and any metal chlorides that pass through the sample train filter. The train-total emissions represent the sum of the front-half and back-half emissions.

As shown in Table 5-16, the average as-measured train-total chloride emissions concentration was approximately 39 mg/dscm (0.016 gr/dscf). Corrected to 3 percent O_2 using the Radian CEM data, this corresponds to approximately 93 mg/dscm @ 3% O_2 (0.04 gr/dscf @ 3% O_2). The train-total chloride mass emission rate from the afterburner exhaust stack was about 0.47 kg/hr (1.0 lb/hr). The majority of the chloride emissions were found in the back-half of the HCl sample train, indicating very little particulate chloride in the emissions.

5.6 DRUM FURNACE FEED SAMPLE ANALYSES

As discussed in Section 4.2, two furnace feed material categories were sampled at Site DBR-A. These were drum coatings and drum residues. These samples were analyzed for chlorinated benzenes, chlorinated biphenyls and chlorinated phenols. In addition, a composite of the drum residue samples was analyzed for total organic halide (TOX) and dioxin/furan homologues.

TABLE 5-15. AFTERBURNER REMOVAL EFFICIENCIES AT SITE DBR-A

Homologue	Afterburner Removal Efficiency, (%)			
	Run 1	Run 2	Run 3	Average
Dioxins				
2378 TCDD	99.1	99.5	98.0	98.9
Other-TCDD	93.4	95.0	95.7	94.7
Penta-CDD	96.1	98.2	98.9	97.7
Hexa-CDD	96.4	95.8	99.0	97.1
Hepta-CDD	98.8	81.2	98.8	92.9
Octa-CDD	98.3	77.7	95.3	90.4
Total PCDD	97.9	94.3	98.3	96.8
Furans				
2378 TCDF	92.4	97.1	96.5	95.3
Other TCDF	94.0	92.1	96.6	94.2
Penta-CDF	95.9	95.3	97.9	96.4
Hexa-CDF	92.1	87.5	98.3	92.6
Hepta-CDF	98.2	80.3	98.1	92.2
Octa-CDF	98.5	75.7	98.0	90.7
Total PCDF	95.6	92.7	97.4	95.2

TABLE 5-16. HCl TRAIN CHLORIDE EMISSIONS DATA FOR SITE DBR-A

Sample Component	Test Run	Emissions Concentration mg/dscm	ppmv[a]	mg/dscm @ 3% O_2[b]	Emissions Rate (kg/hr)
Train Total	Run 01	64.7	44.5	153	0.76
	Run 02	28.0	19.3	66.3	0.36
	Run 03	25.3	17.4	59.9	0.30
	Average	39.3	27.1	93.1	0.47
Front Half	Run 01	0.30	0.20	0.71	0.003
	Run 02	0.20	0.14	0.47	0.003
	Run 03	0.00	0.00	0.00	0.00
	Average	0.17	0.11	0.39	0.002
Back Half	Run 01	64.4	44.3	152	0.76
	Run 02	27.8	19.1	65.8	0.35
	Run 03	25.3	17.4	59.9	0.300
	Average	39.2	26.9	92.7	0.47

[a] ppmv = parts per million chloride by volume, dry basis at actual stack O_2 concentration

[b] Concentration corrected to 3% O_2 using the equation:

$[Cl^-]$ @ 3% O_2 = $[Cl^-]$, as measured x $(20.9 - 3)/(20.9 - \% O_2)$

where: % O_2 = oxygen concentration in stack gas as measured by the Radian CEM system (See Table 5-3)

Table 5-17 summarizes the results of the compound-specific precursor analyses. The drum residue samples were found to contain small quantities of chlorinated benzenes (33 ppm). Chlorinated biphenyls and chlorinated phenols were not detected. None of the precursor compounds analyzed for were found in the drum coating samples.

A composite of the drum residue samples from Site DBR-A was analyzed using the TOX procedures. The composite sample contained approximately 800 ppm total TOX. Thus, although the specific precursors analyzed for (chlorobenzenes, chlorinated biphenyls and chlorophenols) were either not detected or were found only in small quantities, there were significant quantities of halogenated species present. This suggests that either 1) the specific precursors analyzed for were present in the samples but were not easily detected using the GC/MS procedure due to the complexity of the sample matrix, or 2) halogenated species other than the specific precursors analyzed for were present in the samples.

Drum residue samples from Runs 01 and 02 were analyzed for dioxin/furan content by Troika. The results of these analyses are shown in Table 5-18. Small amounts of the hexa-CDD, hepta-CDD, and octa-CDD homologues were detected as well as small amounts of TCDF, hepta-CDF, and octa-CDF.

5.7 DIOXIN/FURAN ANALYSIS OF FURNACE ASH SAMPLES

Samples of the drum furnace outlet ash and the inlet ash were analyzed for dioxin/furan content by Troika. Some of these samples could not be successfully analyzed due to some type of contamination which destroyed the HRGC resolution and HRMS sensitivity. Results were obtained, however, for most of the furnace inlet ash samples. In these samples, all species analyzed for were detected except for the 2378-TCDD isomer and the penta-CDD homologue. The reported values for all of the homologues are presented in Table 5-19. Results of the analysis for a sample of bottom ash taken during a pre-survey of the test site are also shown in Table 5-19.

5.8 AMBIENT XAD TRAIN DATA

Dioxin and furan concentration data for ambient air samples taken near the drum furnace outlet are shown in Table 5-20. The sampler was located

TABLE 5-17. SUMMARY OF DIOXIN PRECURSOR DATA FOR SITE DBR-A FEED SAMPLES

Precursor Categories	Precursor Concentration, ug/g (ppm)	
	Drum Coatings	Drum Residues
Total Chlorinated Benzenes	ND	33
Total Chlorinated Biphenyls	ND	ND
Total Chlorinated Phenols	ND	ND
Total Organic Halide (TOX)	NA	800

ND = not detected.
NA = not analyzed.

TABLE 5-18. DIOXIN/FURAN CONCENTRATION DATA FOR SITE DBR-A DRUM RESIDUE SAMPLES

Isomer/Homologue	Concentration (ppb) Run 01	Concentration (ppb) Run 02
Dioxins		
2378 TCDD	ND (0.01)	ND (0.04)
Other TCDD	ND (0.02)	ND (0.07)
Penta CDD	ND (0.04)	ND (0.06)
Hexa CDD	ND (0.05)	0.1
Hepta CDD	0.1	ND (0.07)
Octa CDD	2.0	0.8
Furans		
2378 TCDF	ND (0.02)	ND (0.05)
Other TCDF	0.04	ND (0.2)
Penta CDF	ND (0.07)	ND (0.04)
Hexa CDF	ND (0.05)	ND (0.2)
Hepta CDF	ND (0.08)	0.05
Octa CDF	0.3	ND (0.07)

ND - Not detected at specified minimum limit of detection.

TABLE 5-19. DIOXIN/FURAN CONCENTRATION DATA FOR SITE DBR-A ASH SAMPLES

Isomer/Homologue	Concentration (ppb)						
	Furnace Inlet			Furnace Outlet			
	01	Run 02	03	01	Run 02	03	Presurvey Bottom Ash
Dioxins							
2378 TCDD	a	ND (0.03)	--	a	a	b	b
Other-TCDD	0.2	0.06	0.2	0.6	1.0	b	0.07
Penta-CDD	a	ND (0.6)	ND (0.03)	a	a	b	0.02
Hexa-CDD	a	0.5	0.5	a	a	b	b
Hepta-CDD	a	1.2	2.6	a	a	b	b
Octa-CDD	a	1.4	25.8	a	0.37	b	b
TOTAL PCDD	0.2	3.16	29.1	0.6	1.37	b	0.09
Furans							
2378 TCDF	a	0.2	--	a	a	b	b
Other TCDF	2.6	8.2	2.2	6.4	13.9	b	0.7
Penta-CDF	a	6.4	0.9	a	a	b	0.02
Hexa-CDF	a	4.6	1.1	a	a	b	b
Hepta-CDF	a	4.5	1.1	a	a	b	b
Octa-CDF	a	1.3	0.6	a	0.31	b	b
TOTAL PCDF	2.6	25.2	5.9	6.4	14.2	b	0.09

[a] The analytical results do not satisfy QA requirements.

[b] Meaningful collection or analyses could not be obtained.

ND = Not detected at specified minimum limits of detection.

"--" means sample was not analyzed for this isomer.

TABLE 5-20. AMBIENT AIR DIOXIN/FURAN CONCENTRATION DATA FOR SITE DBR-A[a]

Isomer/Homologue	Concentration (ng/dscm)
Dioxins	
2378 TCDD	ND
Other TCDD	1.48×10^{-1}
Penta CDD	6.67×10^{-2}
Hexa CDD	6.67×10^{-2}
Hepta CDD	7.41×10^{-2}
Octa CDD	2.96×10^{-2}
Total PCDD	3.85×10^{-1}
Furans	
2378 TCDF	4.44×10^{-2}
Other TCDF	1.84×10^{0}
Penta CDF	6.59×10^{-1}
Hexa CDF	4.15×10^{-1}
Hepta CDF	2.3×10^{0}
Octa CDF	6.67×10^{-2}
Total PCDF	5.32×10^{0}

[a] Sampler was located within visible plume of the incinerator making these samples more like process fugitive samples.

within the visible plume of the incinerator, making these samples more like process fugitive samples than ambient air samples. Small but detectable quantities were found of all species analyzed for except the 2378-TCDD isomer, which was not detected. Measured ambient air concentrations of total PCDD and total PCDF were 0.39 ng/dscm and 5.32 ng/dscm, respectively.

5.9 SOIL SAMPLING DATA

Dioxin/furan analyses have not yet been performed on the soil sample obtained at Site DBR-A. The sample is being stored by Radian/RTP.

6.0 SAMPLING LOCATIONS AND PROCEDURES

Samples were collected from seven different locations at Site DBR-A. Three of the locations were for gaseous sampling, and four were for solids sampling. The source sampling and analysis matrix in Table 4-1 lists the sample locations, measured parameters, sampling methods, and analytical methods used.

Details on the sampling locations and methods are discussed in Sections 6.1 through 6.3. Continuous monitoring procedures for CO, CO_2, O_2, NO_x, and THC are included in Section 6.1.

6.1 GASEOUS SAMPLING

Four types of gaseous samples were taken during this test program: Modified Method 5 (MM5), HCl, EPA Method 3, and continuous monitoring (CEM). The sampling locations and methods are further discussed in this section.

6.1.1 Gaseous Sampling Locations

6.1.1.1 Afterburner Outlet Exhaust Stack

The afterburner outlet exhaust stack sampling location is shown as Point A in Figure 4-1. This location was used for dioxin sampling using MM5 and HCl sampling as described in Section 6.1.2 and also for CEM sampling. Gas velocity, molecular weight, and moisture were determined using Methods 1-4.

The dimensions of the afterburner stack are shown in Figure 6-1. The existing stack is 36 inches in diameter and the top of the stack is 29 feet from ground level. The stack is refractory lined. In order to avoid damage to the refractory lining, a temporary stack extension was added for testing purposes. This extension was 36" diameter steel with no lining. The extension was 8' long. The inside diameter of the stack extension was the same as the stack inside dimension. Two 4" diameter ports were provided on the stack extension as shown in Figure 6-1. The ports were located so that more than eight and two equivalent stack diameters of straight run are available upstream and downstream, respectively. Eight traverse points were required for sampling. A single 4" port was provided 2' 6" upstream of the MM5 sampling ports for the CEM probe. The port was oriented at 45° to the MM5 ports so that the CEM probe would not distort the flow profiles for dioxin

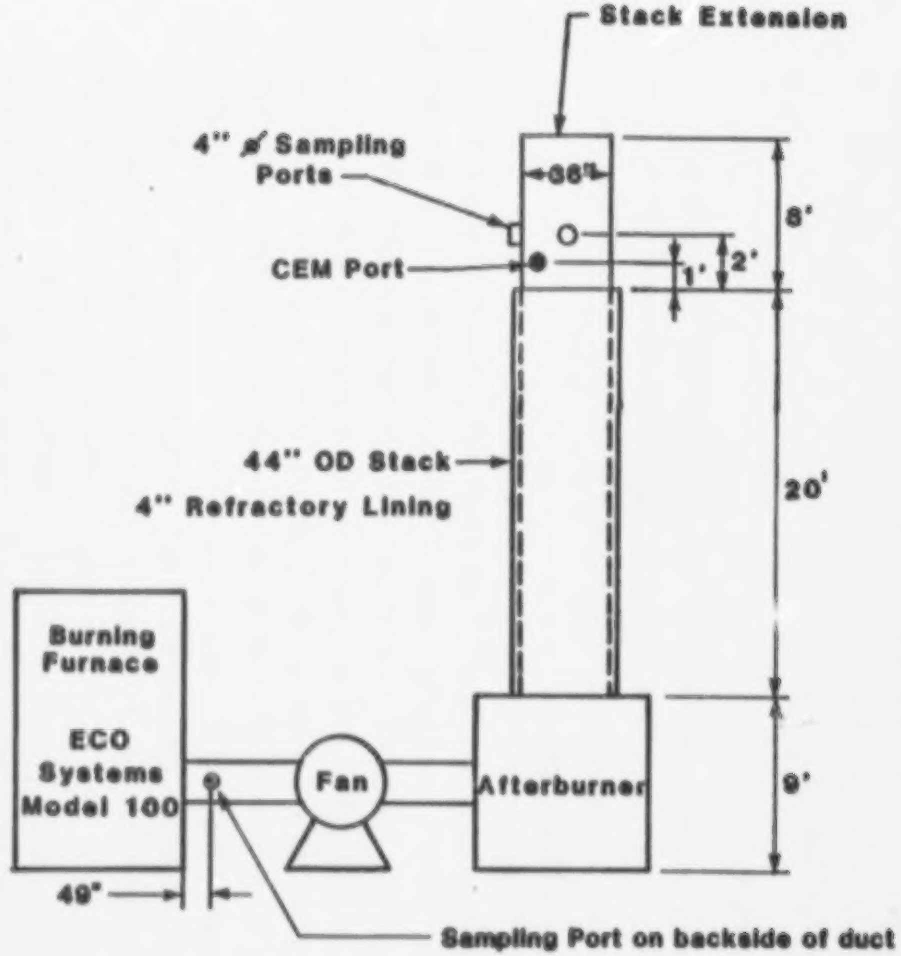
Stack Extension
4" ⌀ Sampling
Ports
CEM Port
36"
8'
2'
1'
20'
44" OD Stack
4" Refractory Lining
Burning
Furnace
ECO
Systems
Model 100
Fan
Afterburner
9'
49"
Sampling Port on backside of duct

Figure 6-1. Exhaust Gas Stack Sampling Location.

sampling. Radian was responsible for designing and fabricating the stack extension and coordinating the installation of the extension with the host facility.

6.1.1.2 Furnace Outlet Exhaust Duct

A sample of the furnace flue gases was collected using a fixed-point MM5 train. A single 4-inch sampling port was added on the horizontal duct before the induced draft fan (Location G on Figure 4-1). The samples collected were analyzed for dioxin/furans.

6.1.2 Gas Sampling Procedures

Gas sampling procedures used during this program are discussed in detail in the Tier 4 Quality Assurance Project Plan (QAPP). A summary of the gas sampling methods used at Site DBR-A is given in Table 6-1, and a brief description of each method is provided in the following sections.

6.1.2.1 Modified Method 5 (MM5)

Gas sampling for dioxins was conducted according to the October 1984 draft of the ASME chlorinated organic compound sampling protocol with two exceptions. This sampling method is a modified version of EPA Method 5 that includes a solid sorbent module for trapping vapor phase organics. The only differences in the sampling protocol which were not discussed in the Tier 4 QAPP are:

1. Benzene was substituted for hexane or toluene as both the cleanup and extractant solvent for both the MM5 filters and the XAD-2 resin. This was due to a discrepancy between the draft ASME sampling protocol and the draft ASME analytical protocol (November 16, 1985).
2. Methylene chloride was substituted for hexane as the final field rinse solvent for the MM5 train. Methylene chloride was also substituted for hexane in the glassware cleaning procedure. This was caused by a high field blank train (February 27, 1985).

MM5 sampling trains were used to collect samples at the afterburner outlet exhaust stack and incinerator outlet exhaust duct. A total of three MM5 test runs per location were conducted, with one test run being conducted per test day. The MM5 samples at both locations were collected isokinetically over approximately a 4 hour sampling period in order to provide minimum sample

TABLE 6- 1. SUMMARY OF GAS SAMPLING METHODS FOR SITE DBR-A

Sample Location	Sample Type or Parameter	Sample Collection Method
Afterburner outlet exhaust stack	Dioxin	Modified EPA Method 5
	Volumetric flow	EPA Method 2
	Molecular weight	EPA Method 3
	Moisture	EPA Method 4
	HCl	HCl train
	CO, CO_2, O_2, NO_x, SO_2, and THC monitoring	Continuous monitoring
Furnace outlet exhaust duct	Dioxin	Fixed Point Modified EPA Method 5

volumes of approximately 3.4 dscm (120 dscf). The MM5 sampling rate was targeted to be between 0.014 and 0.021 scmm (0.5 and 0.75 scfm). At the incinerator outlet exhaust duct an average of 4.0 dscm (140 dscf) of gas was sampled at an average rate of 0.017 scmm (0.6 scfm). At the afterburner outlet exhaust stack an average of 3.68 dscm (130 dscf) of gas was sampled at an average rate of 0.014 scmm (0.5 scfm).

Following sample recovery, the various parts of the sample (filter, solvent rinses, sorbent trap, etc.) were sent to EPA's Troika laboratories, ECL-BSL and EMSL-RTP, to quantify the 2378-TCDD isomer, tetra- through octa-dioxin homologues, and tetra- through octa-furan homologues present in the samples.

A schematic diagram of the MM5 sampling train is shown in Figure 6-2. Flue gas is pulled from the stack through a nozzle and a glass probe. Due to the high stack gas temperatures, a water cooled probe was used at this test site. Particulate matter is removed from the gas stream by means of a glass fiber filter housed in a Teflon-sealed glass filter holder maintained at 120 ± 14^{o}C (248 ± 25^{o}F). The gas passes through a sorbent trap similar to that illustrated in Figure 6-3 for removal of organic constituents. The trap consists of separate sections for 1) cooling the gas stream, and 2) adsorbing the organic compounds on Amberlite XAD-2^{R} resin (XAD). A chilled impinger train following the sorbent trap is used to remove water from the flue gas, and a dry gas meter is used to measure the sample gas flow.

6.1.2.2 Ambient Air Sampling

A schematic diagram of the "ambient XAD" sample train is shown in Figure 6-4. The ambient train consists of a short glass probe, sorbent trap, knockout impinger (optional), silica gel impinger, umbilical line, pump, and dry gas meter. Ambient air was drawn into the sorbent module, where it was cooled to 20^{o}C (68^{o}F) or lower, and the organic constituents were adsorbed by the XAD resin. The gas was then dried with the silica gel and the sample volume measured by the dry gas meter.

Both ambient XAD sample trains were leak-tested before and after each test run at 2.5 kPa (10 inches H_2O) to ensure that the total leakage was less than 0.02 cfm. The dry gas meter reading was recorded twice daily at the

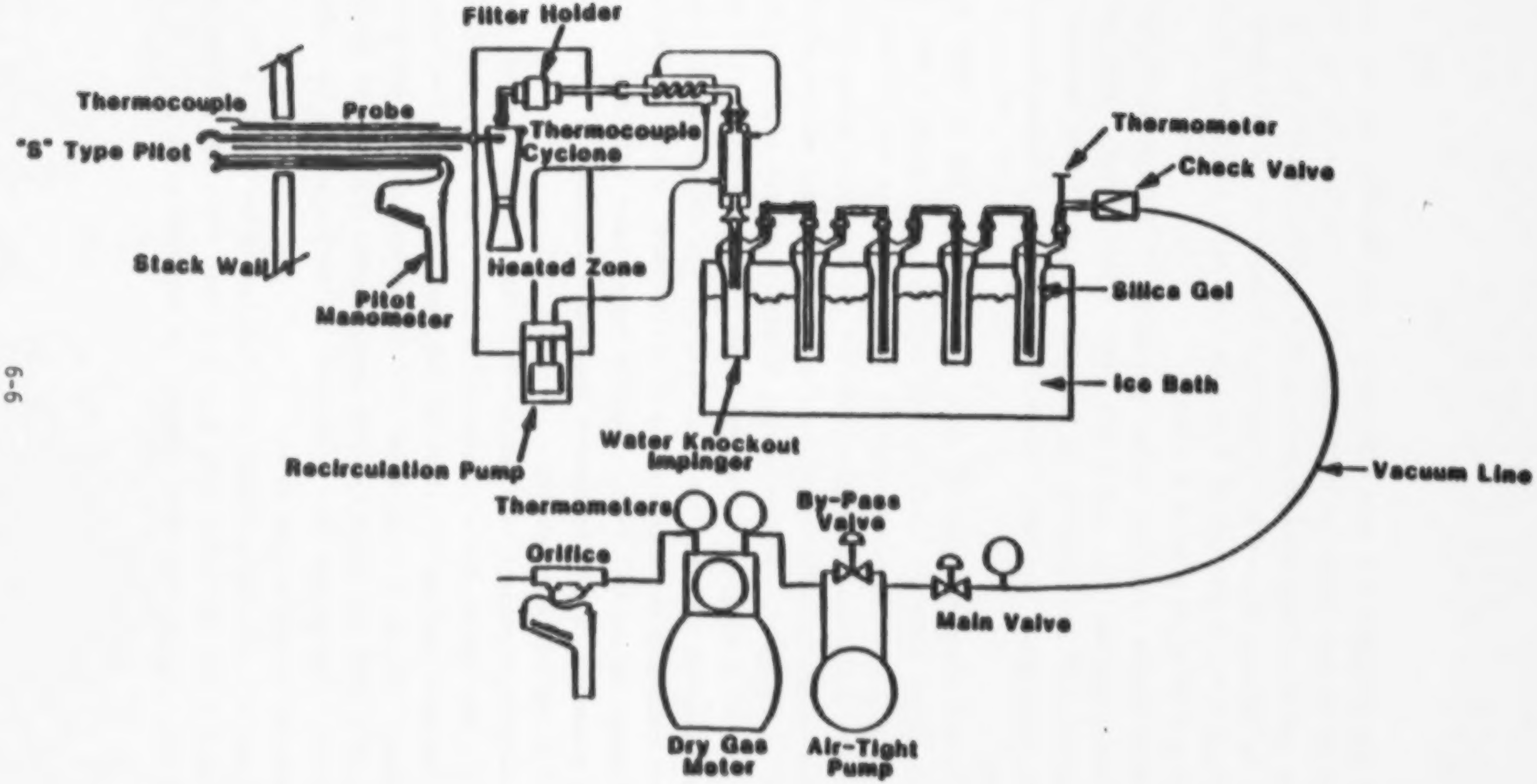
Filter Holder
Thermocouple
Probe
"S" Type Pilot
Thermocouple
Cyclone
Stack Wall
Pitot Manometer
Heated Zone
Recirculation Pump
Water Knockout Impinger
Thermometer
Check Valve
Silica Gel
Ice Bath
Vacuum Line
Thermometers
Orifice
By-Pass Valve
Main Valve
Dry Gas Meter
Air-Tight Pump

Figure 6-2. Modified Method 5 Train.

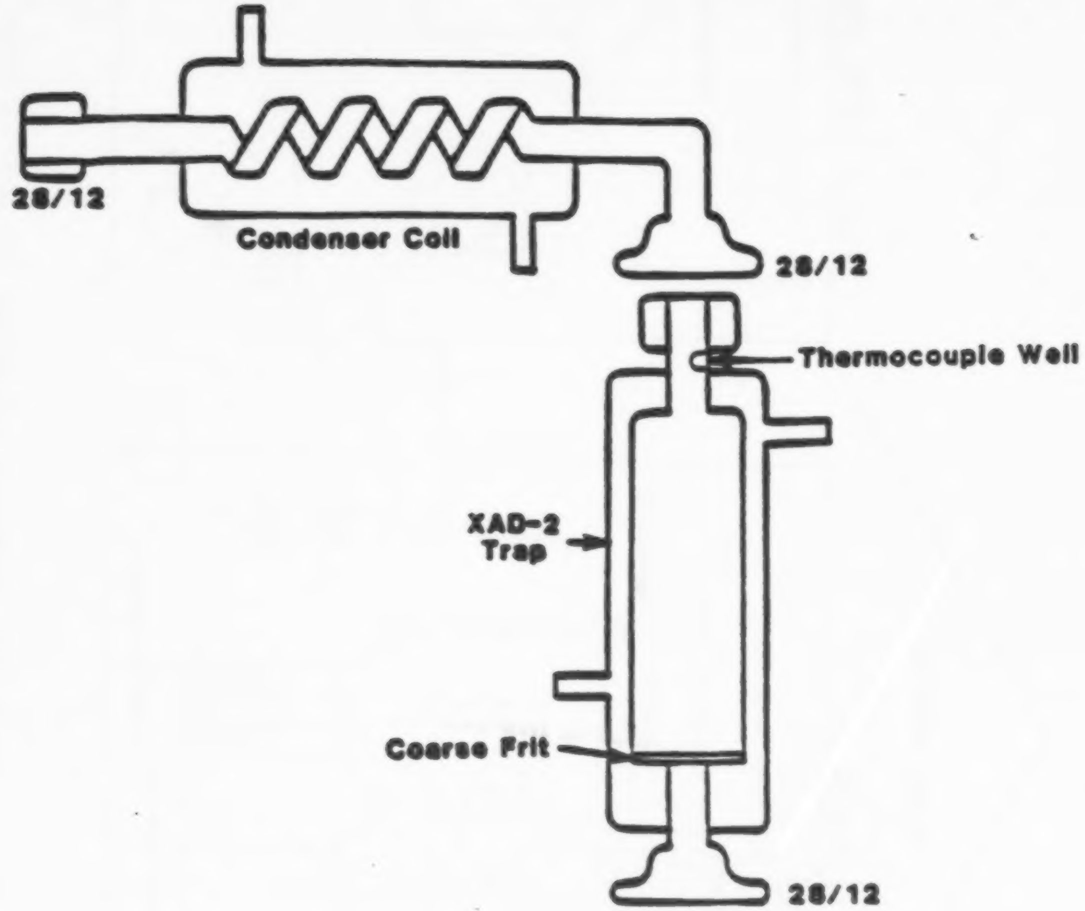
28/12
Condenser Coil
28/12
Thermocouple Well
XAD-2 Trap
Coarse Frit
28/12

Figure 6-3. Adsorbent Sampling System.

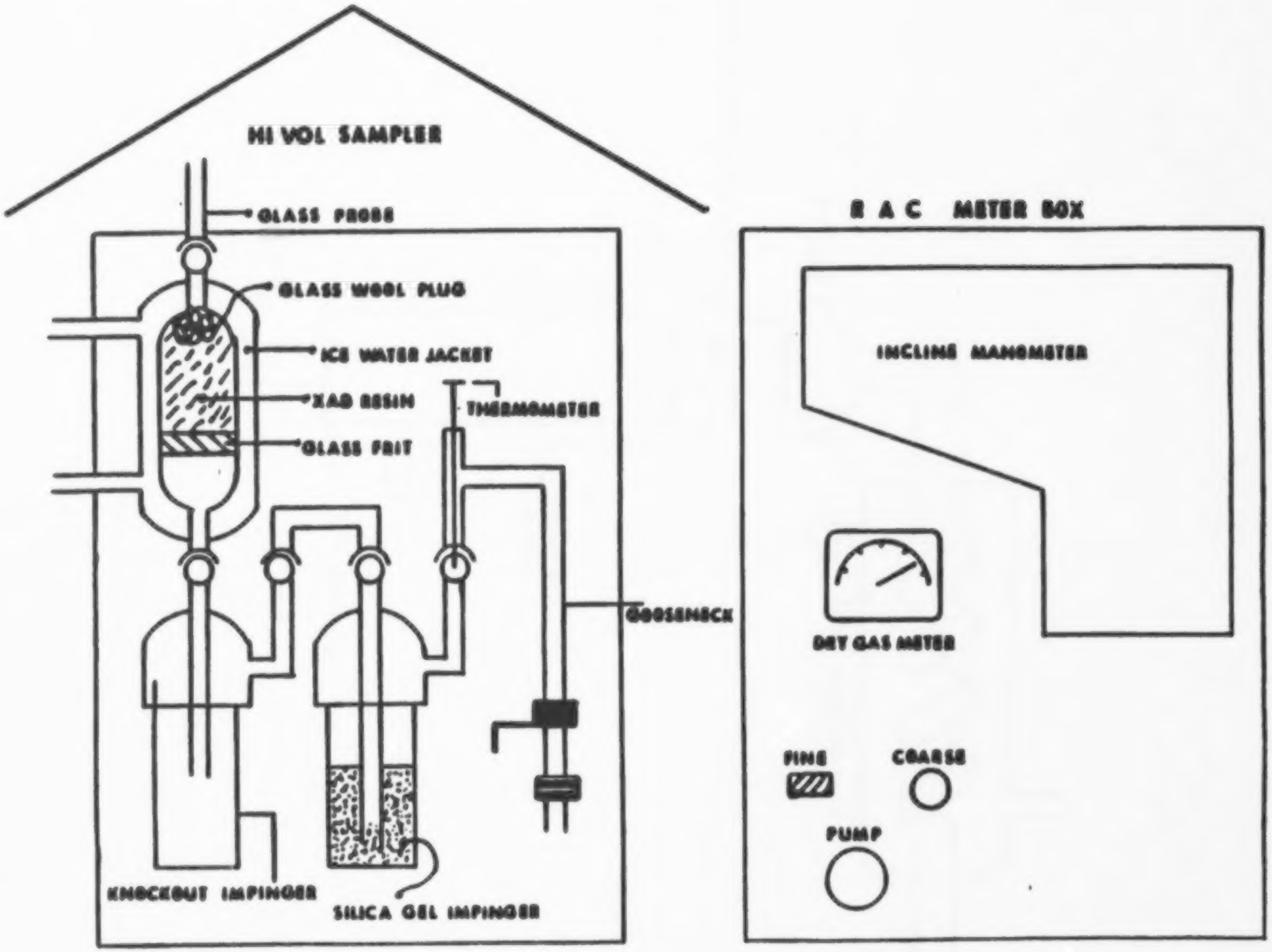
HI VOL SAMPLER
GLASS PROBE
GLASS WOOL PLUG
ICE WATER JACKET
XAD RESIN
GLASS FRIT
THERMOMETER
GOOSENECK
KNOCKOUT IMPINGER
SILICA GEL IMPINGER
R A C METER BOX
INCLINE MANOMETER
DRY GAS METER
FINE
COARSE
PUMP

Figure 6-4. Components of Ambient Air Sampling Train.

beginning and end of each test period. The dry gas meter temperature, ice bath temperatures, pressure, and volume were recorded once per hour during the sampling periods. Although the sampling pump was operated only during MM5 sampling, the sorbent traps were cooled continuously (24 hours/day) to 20°C (68°F) or lower.

Recovery of the ambient XAD sample trains was performed in a manner similar to that of the MM5 train. The probe was rinsed with acetone and methylene chloride three times each, and the rinse and condensate were stored in a single sample container. The sorbent trap was capped with ground glass caps. The ambient air sample consisted of the rinse and the sorbent trap. The samples were shipped from the field to Troika for dioxin/furan analysis and returned to Radian for dioxin precursor analysis.

6.1.2.3 HCl Determination

HCl concentrations in the outlet exhaust stack were determined using another modification of EPA Method 5. The sample train components and operation were identical to those of Method 5 with the following exceptions:

1. Water in the first two impingers was replaced with 0.1 M NaOH.
2. Sampling was single point isokinetic with the nozzle placed at a point in the stack having an approximate average velocity.
3. The moisture/NaOH in the impingers was saved for ion chromatography analysis. The impinger catches were analyzed by Radian's Research Triangle Park (RTP), North Carolina, laboratory.
4. A quartz probe was used. Recovery of the HCl train provided a sample consisting of three components: probe rinse, filter, and back-half rinse/impinger catch.

6.1.2.4 Volumetric Gas Flow Rate Determination

The volumetric gas flow rates were determined using EPA Method 2. Based on this method, the volumetric gas flow rate was determined by measuring the average velocity of the flue gas and the cross-sectional area of the duct. The average flue gas velocity was calculated from the average gas velocity pressure across an S-type pitot tube, the average flue gas temperature, the wet molecular weight, and the absolute static pressure.

6.1.2.5 Flue Gas Moisture Determination

The moisture content of the flue gas was determined using EPA Method 4. Based on this method, a known volume of particulate-free gas was pulled through a chilled impinger train. The quantity of condensed water was determined gravimetrically and then related to the volume of gas sampled to determine the moisture content.

6.1.2.6 Flue Gas Molecular Weight Determination

The integrated sampling technique described by EPA Method 3 was used to obtain a composite flue gas sample for fixed gas (O_2, CO_2, N_2) analysis. The fixed gas analysis was used to determine the molecular weight of the gas stream. A small diaphragm pump and a stainless steel probe were used to extract single point flue gas samples. The samples were collected at the MM5 sampling ports using Tedlar^R bags. Moisture was removed from the gas sample by a water-cooled condenser so that the fixed gas analysis was on a dry basis.

The composition of the gas sample was determined using a Shimadzu Model 3BT analyzer as opposed to the Fyrite or Orsat analyzer prescribed by Method 3. The Shimadzu instrument employs a gas chromatograph and a thermal conductivity detector to determine the fixed gas composition of the sample.

6.1.2.7 Continuous Monitors

Continuous monitoring was performed at the afterburner exhaust sampling location for O_2, CO_2, CO, NO_x, SO_2, and THC throughout the dioxin sampling test period each test day. The primary objectives of the continuous monitoring effort were to observe fluctuations in flue gas parameters and to provide an indication of combustion conditions. Sample acquisition was accomplished using an in-stack filter probe and Teflon sample line connected to a mobile laboratory. The heat-traced sample line was maintained at a temperature of at least 120°C to prevent condensation in the sample line. The stack gas sample was drawn through a sample gas conditioner, which consisted of an ice bath and knockout trap. The sample gas conditioner removed moisture and thus provided a dry gas stream for analysis. A separate unconditioned gas stream was supplied to the THC analyzer for analysis on a wet basis.

An Anarad Model 412 nondispersive infrared (NDIR) analyzer was used to measure CO and CO_2; a Beckman Model 755 paramagnetic analyzer was used to measure O_2; a TECO Model 10AR chemiluminescent analyzer was used to measure

NO_x; a TECO Model 40 pulsed fluorescence analyzer was used for SO_2; and a Beckman Model 402 flame ionization analyzer was used to measure THC.

6.2 SOLID SAMPLING

Four different solid samples were collected during this test program: feed samples, two types of ash samples, and soil samples. The sampling locations and methods are discussed below.

6.2.1 Feed Sampling

The furnace feed was characterized by a systematic drum sampling approach. The procedure implemented was as follows. Every tenth drum from the feed conveyor was sampled prior to the drums being inverted. The contents (as indicated by labeling information) were recorded for each drum sampled. An aliquot of the residue in the drum was collected using a ladle. The size of the sample was kept the same to the extent possible. The estimated sample volume was 20 to 100 ml. A sample of the outer paint was removed using a scraper. These samples were combined into one composite for precursor and dioxin/furan analysis.

This sampling approach provided information concerning the compounds that were present in the feed to the furnace. However, the size of the aliquots were not weighted to represent the relative amounts of residues, linings and paint that were present in and on each drum, and from drum-to-drum. The composition data were used to compare the feed materials between runs 1, 2, and 3, but those results do not represent true feed composition on a weight percent basis.

6.2.2 Ash Sampling

Two different ash samples were obtained from this site: furnace inlet bottom ash and furnace outlet bottom ash. Hourly grab samples of the furnace bottom ash were collected at the conveyor outfall area and also at the feed end of the furnace during each test run. The grab samples were composited into one sample for each location and for each test run. These samples were shipped to Troika for dioxin/furan analysis.

6.2.3 Soil Sampling

The fourth solid sample was a composite soil sample comprised of 10 individual soil samples. The soil sampling protocol for Tiers 3, 5, 6, and 7 of the National Dioxin Study is specified in the document, "Sampling Guidance Manual for the National Dioxin Study." A similar protocol was used for soil sampling at Site DBR-A. A total of 10 soil sampling locations was selected according to the directed site selection approach described in the above mentioned document. The 10 individual soil sampling locations are shown in Figure 6-5. Soil samples were collected by forcing a bulb planter into the soil to a depth of 3 inches. The soil samples were composited in a clean stainless steel bucket. Five hundred grams of the composite were placed in a 950 ml amber glass bottle and archived at Radian for potential dioxin/furan analysis by Troika.

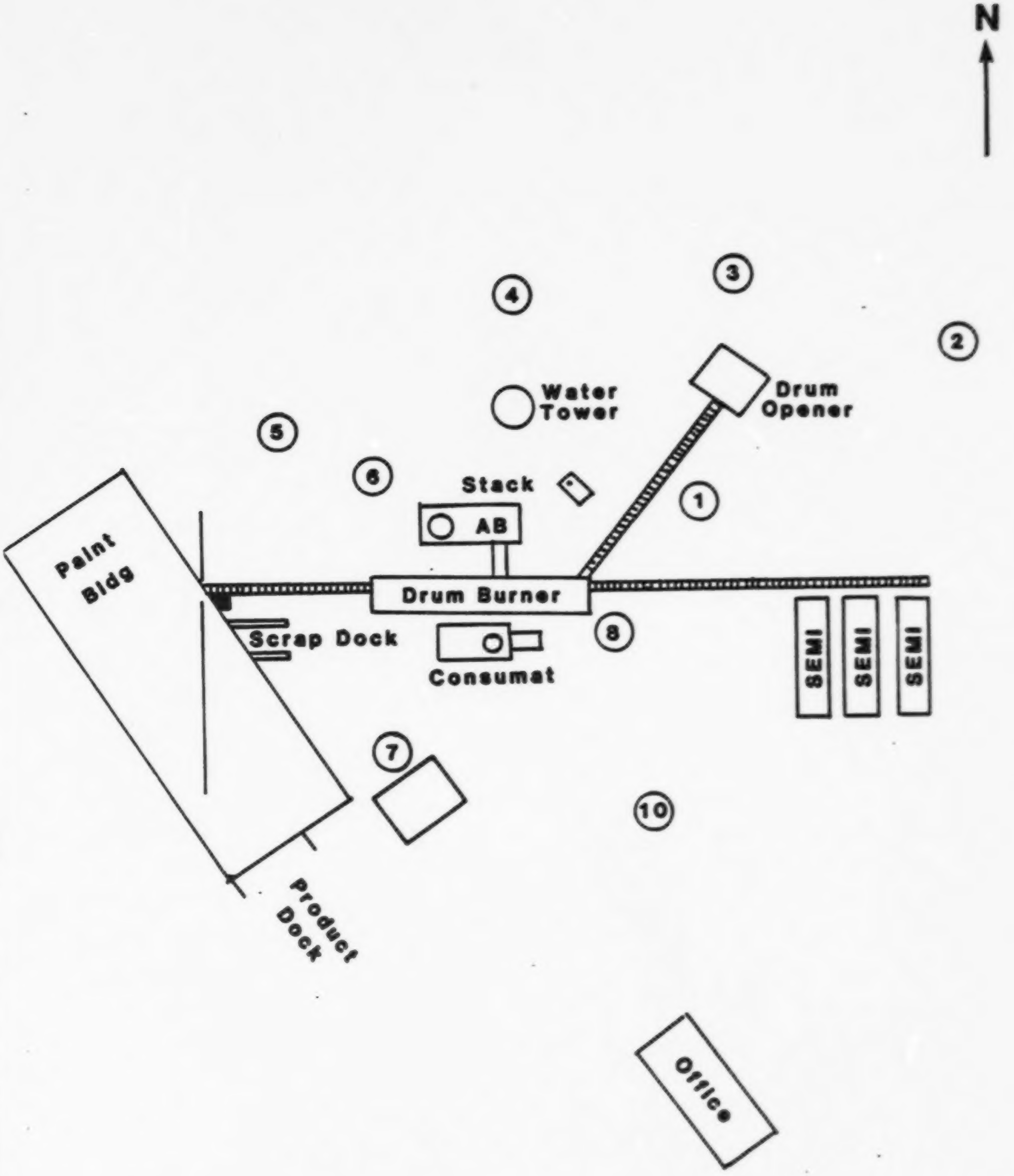
N
③
④
②
Water Tower
Drum Opener
⑤
⑥
Stack
①
AB
Paint Bldg
Drum Burner
Scrap Dock
⑧
Consumat
SEMI
SEMI
SEMI
⑦
⑨
⑩
Product Dock
Office

Figure 6-5. Site Plot Plan and Soil Sampling Locations, Site 11

7.0 ANALYTICAL PROCEDURES

Laboratory procedures used to quantify dioxins/furans and dioxin/furan precursors in the Tier 4 samples are described in this section. Samples analyzed by EPA's Troika laboratories for dioxin/furan content included MM5 train samples, ash samples, and ambient XAD train samples. Procedures used for the dioxin/furan analyses are described in detail in the addendum to Analytical Procedures and QA Plan for Tiers 3-6 of the National Dioxin Study.[1] These procedures are summarized in Section 7.1. Furnace feed samples were analyzed by Radian to determine concentrations of chlorinated phenols (CP), chlorobenzenes (CB), polychlorinated biphenyls (PCB), and total organic halogen (TOX). Procedures used for these analyses are detailed in Sections 7.2 and 7.3, respectively.

7.1 DIOXINS/FURANS

The analytical procedures summarized in this section were used by Troika for dioxin/furan analysis of MM5 train samples, ash samples and ambient XAD train samples from Site DBR-A. A separate document detailing these procedures has been prepared.[1]

Samples consisting of organic solvents, aqueous solutions, and solids were prepared for analysis using slightly different procedures. The organic solvent samples consisted of rinses from the MM5 probe, nozzle, filter housing and condenser coil. Aqueous samples consisted of impinger catch solutions, and solid samples included filters, XAD resin, and ash. Isotopically-labeled surrogate compounds were added to all samples prior to extraction to allow determination of method efficiency and for quantification purposes.

Organic liquid samples (e.g., acetone and methylene chloride-based MM5 train rinses) were concentrated using a nitrogen blowdown apparatus. The residue, which contained particulate matter from the MM5 train probe and nozzle, was combined with the filter and handled as a solid sample. Solid samples were extracted with benzene in a Soxhlet apparatus for a period of at least 16 hours. The extract was concentrated by nitrogen blowdown and subjected to chromatographic cleanup procedures.

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[1] Analytical Procedures and Quality Assurance Plan for the Analysis of Tetra Through Octa Chlorinated Dibenzo-p-Dioxins and Dibenzofurans in Samples from Tier 4 Incineration Processes. Addendum to: "Analytical Procedures and Quality Assurance Plan for the Analysis of 2378-TCDD in Tier 3-7 Samples of the U.S. Environmental Protection Agency National Dioxin Strategy." EPA/600/3-85-019, April 1985.

Aqueous solutions (e.g., MM5 train impinger samples) were extracted with hexane by vigorous shaking for a three hour period. This extraction procedure was repeated three times, with the organic fractions ultimately being combined and concentrated for chromatographic cleanup.

The cleanup procedure involved using liquid chromatographic columns to separate the compounds of interest from other compounds present in the samples. Four different types of columns were used: a combination acid and base-modified silica gel column, a basic alumina column, a PX-21 carbon/celite 545 column and a silica/diol micro column. These were used in successive steps, with the last two being used only if necessary.

The cleaned samples were analyzed using high resolution gas chromatography/high resolution mass spectrometry (GC/MS). The conditions for the analyses were as follows:

Gas Chromatograph - Injector configured for capillary column, splitless injection, injector temperature 250°C, helium carrier gas at 1.2 ml/min, initial column temperature 100°C, final column temperature 240°C, interface temperature 270°C.

Mass Spectrometer - Varian/MAT Model 311A, electron energy 70ev, filament emission 1MA, mass resolution 8000 to 10,000, ion source temperature 270°C.

7.2 PRECURSOR ANALYSES

Feed samples for Site DBR-A were analyzed by Radian/RTP for chlorophenols (CP), chlorobenzenes (CB) and polychlorinated biphenyls (PCB) by GC/MS; total organic halides (TOX) by GC/Hall detector. Analytical procedures are discussed in the following sections.

7.2.1 GC/MS Analyses

The analytical procedures used for determining CP, CB, and PCB concentrations in feed samples are modified versions of procedures typically used for the analysis of MM5 train components. These procedures involve initial extraction of the sample with an appropriate solvent, preliminary separation of the compounds of interest by solvent partitioning and liquid chromatography, and analysis of the processed fractions. Solutions containing CB and PCB are injected directly into the GC/MS, and solutions containing CP are derivatized prior to injection. Details on the procedures used for Site DBR-A samples are provided in the sections below.

7.2.1.1 Sample Preparation

A flow chart for the sample preparation procedure used for Site DBR-A feed samples is shown in Figure 7-1. The first step in the procedure involved adding labeled surrogate compounds to provide a measure of extraction method efficiency. The next step involved adding a mixture of 0.5 N NaOH and $MeCl_2$ to the sample and sonicating the sample for 30 minutes. The NaOH and $MeCl_2$ mixture converts the acid compounds to their salts and collects base/neutrals in the organic solvent. The sonicated sample was filtered and rinsed with 0.5 N NaOH. The filtrate was extracted three times in a separatory funnel with $MeCl_2$ and the aqueous and organic fractions were saved for derivatization and/or further cleanup. The aqueous fraction (or acids portion) was acidified to pH 2.0 with HCl and then extracted three times with $MeCl_2$. The $MeCl_2$ from this extraction was dried with anhydrous Na_2SO_4, exchanged to benzene, and concentrated using a nitrogen blowdown apparatus. Acetylation of any CP present in the sample involved the following steps:

1. 2.0 mL iso-octane, 2.0 mL acetonitrile, 50 uL pyridine, and 20 uL acetic anhydride were added to the extract. The test tube containing the extract was placed in a 60°C water bath for 15 minutes and was shaken for 30 seconds every 2 minutes.
2. 6 mL of 0.01 N H_3PO_4 were added to the test tube, and the sample was agitated for 2 minutes on a wrist action shaker.
3. The organic layer was removed and the quantitation standard was added. The sample was concentrated in a Reacti-Vial at room temperature (using prepurified N_2) to 1 mL prior to GC/MS analysis.

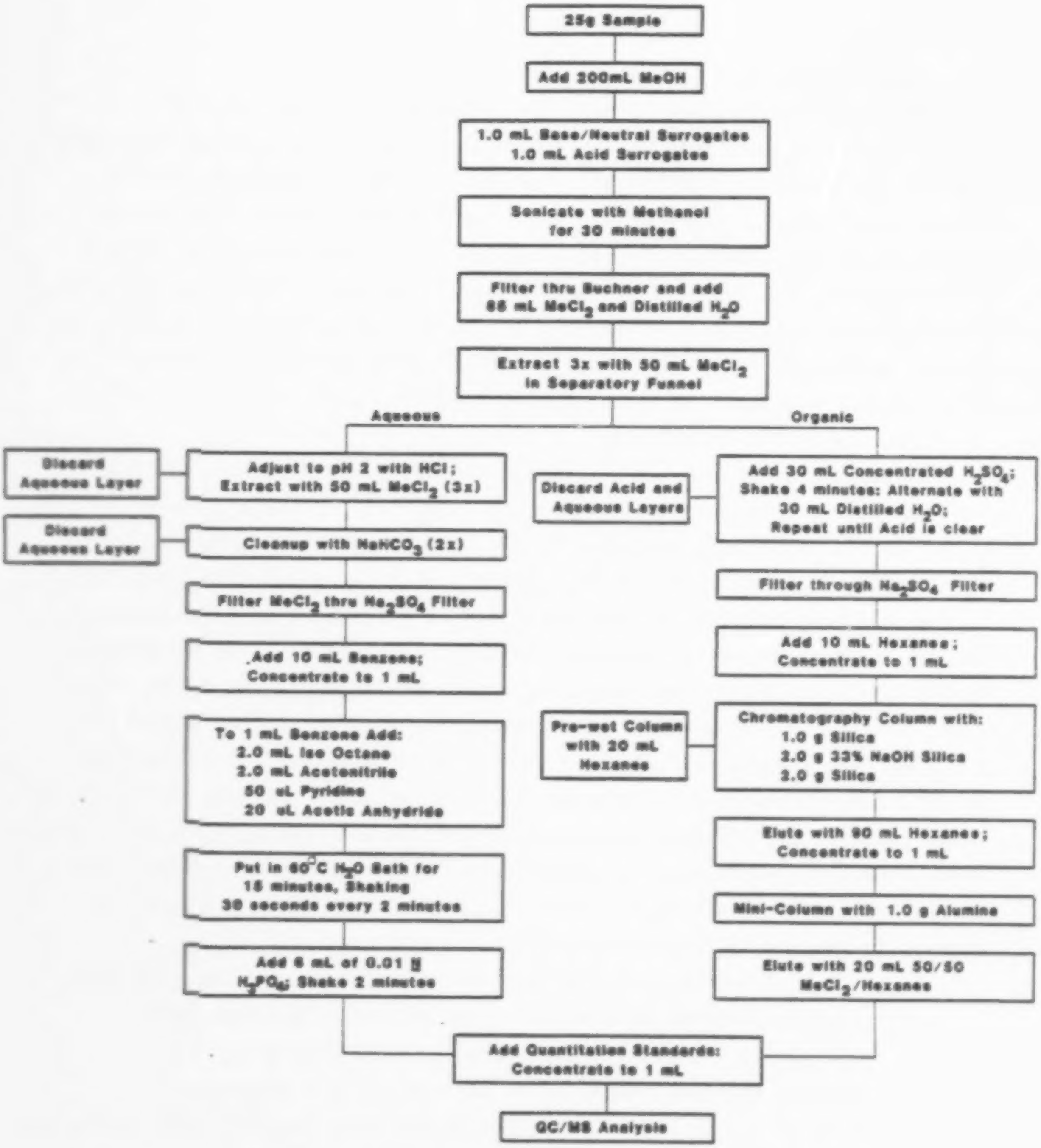
25g Sample
Add 200mL MeOH
1.0 mL Base/Neutral Surrogates 1.0 mL Acid Surrogates
Sonicate with Methanol for 30 minutes
Filter thru Buchner and add 85 mL $MeCl_2$ and Distilled H_2O
Extract 3x with 50 mL $MeCl_2$ in Seperatory Funnel
Aqueous
Organic
Discard Aqueous Layer
Adjust to pH 2 with HCl; Extract with 50 mL $MeCl_2$ (3x)
Discard Aqueous Layer
Cleanup with $NaHCO_3$ (2x)
Filter $MeCl_2$ thru Na_2SO_4 Filter
Add 10 mL Benzene; Concentrate to 1 mL
To 1 mL Benzene Add:
2.0 mL Iso Octane
2.0 mL Acetonitrile
50 uL Pyridine
20 uL Acetic Anhydride
Put in 60°C H_2O Bath for 15 minutes, Shaking 30 seconds every 2 minutes
Add 6 mL of 0.01 N H_3PO_4; Shake 2 minutes
Discard Acid and Aqueous Layers
Add 30 mL Concentrated H_2SO_4; Shake 4 minutes: Alternate with 30 mL Distilled H_2O; Repeat until Acid is clear
Filter through Na_2SO_4 Filter
Add 10 mL Hexanes; Concentrate to 1 mL
Pre-wet Column with 20 mL Hexanes
Chromatography Column with:
1.0 g Silica
2.0 g 33% NaOH Silica
2.0 g Silica
Elute with 90 mL Hexanes; Concentrate to 1 mL
Mini-Column with 1.0 g Alumine
Elute with 20 mL 50/50 $MeCl_2$/Hexanes
Add Quantitation Standards: Concentrate to 1 mL
GC/MS Analysis

Figure 7-1. Sample Preparation Flow Diagram for Site DBR-A Precursor Analyses

Cleanup of the organic (or base/neutrals) layer from the first $MeCl_2$ extraction involved successively washing the extract with concentrated H_2SO_4 and double-distilled water. The acid or water was added in a 30 mL portion and the sample was shaken for two minutes. After the aqueous (or acid) and organic layers were completely separated, the aqueous (or acid) layer was discarded. The acid washing procedure was repeated until the acid layer was colorless. The organic fraction from the final wash was dried with anhydrous Na_2SO_4, exchanged to hexane and concentrated. Final cleanup of the sample by column chromatography involved the following procedure.

A glass macro-column, 20 mm o.d. x 230 mm in length, tapered to 6 mm o.d. on one end, was prepared. The column was packed with a plug of siliconized glass wool, followed successively by 1.0 g silica, 2.0 g silica containing 33 percent (w/w) 1 N NaOH, and 2.0 g silica. The concentrated extract was quantitatively transferred to the column and eluted with 90 mL hexane. The entire eluate was collected and concentrated to a volume of 1 mL in a centrifuge tube.

A disposable liquid chromatography mini-column was constructed by cutting off a 5-mL Pyrex disposable pipette at the 2.0 mL mark and packing the lower portion of the tube with a small plug of siliconized glass wool, followed by 1 g of Woehlm basic alumina. The alumina had been previously activated for at least 16 hours at 600°C in a muffle furnace and cooled in a desiccator for 30 minutes just before use. The concentrated eluate from above was quantitatively transferred onto the liquid chromatography column. The centrifuge tube was rinsed consecutively with two 0.3-mL portions of a 3 percent $MeCl_2$:hexane solution, and the rinses were transferred to the liquid chromatography column.

The liquid chromatography column was eluted with 20 mL of a 50 percent (v/v) $MeCl_2$:hexane solution, and the eluate was concentrated to a volume of approximately 1 mL by heating the tubes in a water bath while passing a stream of prepurified N_2 over the solutions. The quantitation standard was added and the final volume was adjusted to 1.0 mL prior to GC/MS analysis.

7.2.1.2 Analysis

Analyses for CP, CB and PCB present in the feed sample extracts were performed with a Finnigan Model 5100 mass spectrometer using selected ion monitoring. A fused silica capillary column was used for chromatographic separation of the compounds of interest. Analytical conditions for the GC/MS analysis are shown in Table 7-1.

Tuning of the GC/MS was performed daily as specified in the Tier 4 QA Project Plan. An internal-standard calibration procedure was used for sample quantitation. Compounds of interest were calibrated against a fixed concentration of either d_{12}-chrysene (for CP) or d_8-naphthalene (for CB, PCB). Components of the calibration solution are shown in Table 7-2. For multi-point calibrations, this solution was injected at concentrations of 10, 50, 100, and 150 ng/ml.

Compound identification was confirmed by comparison of chromatographic retention times and mass spectra of unknowns with retention times and mass spectra of reference compounds. Since the selected ion monitoring technique was necessary for the samples analyzed, care was taken to monitor a sufficiently wide mass region to avoid the potential for reporting false positives.

The instrument detection limit for the analytes of interest (i.e., CP, CB, and PCB) was estimated to be approximately 500 pg on column. For a 50 g sample and 100 percent recovery of the analyte, this corresponds to a feed sample detection limit of 10 ppb.

7.3 TOTAL CHLORIDE ANALYSES

Furnace feed samples were analyzed for total organic halide (TOX) by short-column GC and a Hall detector (GC/Hall). Solid samples were extracted with benzene for at least 16 hours in a Soxhlet apparatus. The extracts were washed three times with 100 mL portions of reagent-grade water concentrated to 10 mL.

An attempt to use a fused silica capillary column to separate surrogates from target compounds was unsuccessful due to the complexity of the sample constituents. Determinations for TOX were therefore performed on samples without surrogates and no measure of extraction efficiency is available.

Instrument conditions are shown in Table 7-3. Sample quantitation was based on an average response factor developed from a mixture of chlorinated benzenes and brominated biphenyls. CP, CB and PCB were also injected individually at various concentrations to develop a calibration curve for comparison with the mixture response factors.

TABLE 7-1. INSTRUMENT CONDITIONS FOR GC/MS PRECURSOR ANALYSES

Parameter	Chlorobenzenes/ Polychlorinated biphenyls	Chlorophenols
Column	30 m WB DB-5 (1.0 u film thickness) fused silica capillary	
Injector Temperature	290°C	290°C
Separator Oven Temperature	290°C	290°C
Column Head Pressure	9 psi	9 psi
He flow rate	1 mL/min	1 mL/min
GC program	40(4)-290°C, 10°/min & hold	40(1)-290°C, 12°/min & hold
Emission Current	0.50 mA	0.50 mA
Electron Energy	70 eV	70 eV
Injection Mode	Splitless 0.6 min, then 10:1 split	
Mode	Electron ionization, Selected Ion Monitoring	

TABLE 7-2. COMPONENTS OF THE CALIBRATION SOLUTION

Base/Neutrals

4-chlorobiphenyl
3,3'-dichlorobiphenyl
2,4',5-trichlorobiphenyl
3,3'4,4'-tetrachlorobiphenyl
2,2',6,6'-tetrachlorobiphenyl
2,2,4,5,6-pentachlorobiphenyl
2,2',4,4',5,5'-hexachlorobiphenyl
2,2',3,4,4',5',6-heptachlorobiphenyl
2,2',3,3',4,4',5,5'-octachlorobiphenyl
2,2',3,3',4,4',5,6,6'-nonachlorobiphenyl
decachlorobiphenyl
p-dichlorobenzene
1,2,4-trichlorobenzene
1,2,3,5-tetrachlorobenzene
pentachlorobenzene
hexachlorobenzene
d_4-1,4-dichlorobenzene (SS)[1]
3-bromobiphenyl (SS)
2,2',5,5'-tetrabromobiphenyl (SS)
2,2',4,4',6,6'-hexabromobiphenyl (SS)
octachloronaphthalene (QS)[2]
d_{10}-phenanthrene (QS)
d_{12}-chrysene (QS)

Acids

2,5-dichlorophenol
2,3-dichlorophenol
2,6-dichlorophenol
3,5-dichlorophenol
3,4-dichlorophenol
2,3,5-trichlorophenol
2,3,6-trichlorophenol
3,4,5-trichlorophenol
2,4,5-trichlorophenol
2,3,4-trichlorophenol
2,3,5,6-tetrachlorophenol
pentachlorophenol
d_6-phenol (SS)
d_4-2-chlorophenol (SS)
$^{13}C_6$-pentachlorophenol (SS)
d_8-naphthalene (QS)
2,4,6-tribromophenol (QS)
d_{10}-phenanthrene (QS)
d_{12}chrysene (QS)

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[1] Surrogate standard.
[2] Quantitation standard.

TABLE 7-3. ANALYTICAL CONDITIONS FOR TOX ANALYSIS

Hall Detector Conditions

Reactor temperature - 850°C
Solvent - n-propanol
Hydrogen flow rate - 35 mL/min

GC Conditions (Varian 3700)

Injection volume (1 - 5 uL)
Helium carrier gas flow rate - 60 mL/min
Column - 3-ft packed column with 1 in 10% OV 101
Column temperature - 200°C isothermal

8.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

This section summarizes results of quality assurance and quality control (QA/QC) activities for Site DBR-A. Surrogate recoveries for the afterburner outlet samples and ambient XAD train sample were all within the QA targets specified in the Tier 4 QAPP. For the afterburner inlet samples, surrogate recoveries of the labeled TCDD species were within the Tier 4 QA targets, but recoveries of the labeled hepta- and octa-CDD species were not within the QA target of 40 to 120 percent. Surrogate recoveries for the ash samples did not satisfy the Tier 4 QA requirements. The results of the analysis of the fortified laboratory QC sample were all within 44 percent of the true value which is within the Tier 4 objective of ± 50 percent.

The dioxin/furan precursor analysis of the feed samples varied by sample type and by specific surrogate species. Generally, the values were below the 50 percent objective stated in the Tier 4 QAPP. In spite of the relatively low surrogate recovery values for some of the feed samples, the resulting analytical sensitivity for the target analytes is considered acceptable for the purpose of this study.

The following sections summarize the results of all Site DBR-A QA/QC activities. Manual gas sampling methods are considered in Section 8.1 and continuous emission monitoring and molecular weight determinations are considered in Sections 8.2 and 8.3. The laboratory analysis QA/QC activities are summarized in Section 8.4.

8.1 MANUAL GAS SAMPLING

Manual gas sampling methods at Site DBR-A included Modified Method 5 (MM5), EPA Methods 1 through 4, and HCl testing. These methods are discussed in Section 6.0. Quality assurance and quality control (QA/QC) activities for the manual sampling methods centered around 1) equipment calibration, 2) glassware pre-cleaning, 3) procedural QC checks, and 4) sample custody procedures. Key activities and QC results in each of these areas are discussed in this section. Also discussed are problems encountered that may have affected data quality.

8.1.1 Equipment Calibration and Glassware Preparation

Pre-test calibrations or inspections were conducted on pitot tubes, sampling nozzles, temperature sensors and analytical balances. Both pre-test and post-test calibrations were performed on the dry gas meters. All of the field test equipment met the calibration criteria specified in the Tier 4 Quality Assurance Project Plan (QAPP). Differences in the pre-test and post-test dry gas meter calibrations were less than 2.5 percent. The calibration sheets can be found in Appendix A-15.

An extensive pre-cleaning procedure was used for all sample train glassware and sample containers. This cleaning procedure, which is outlined in Table 8-1, was implemented to minimize the potential for sample contamination with substances that could interfere with the dioxin/furan analysis. A blank MM5 train that had been pre-cleaned using this procedure (i.e., proof train blank) was recovered with acetone and methylene chloride rinses according to the usual MM5 recovery procedure. The rinses and other MM5 train components of the proof train blank (i.e., filter, XAD trap, and impinger solution) were submitted to Troika for dioxin/furan analysis. To minimize the potential for contamination in the field, all sample train glassware was capped with foil prior to use. A sample trailer was maintained for the specific purpose of sample train assembly and recovery. A blank MM5 train that had been previously used and field-recovered at least once at Site DBR-A (i.e., field recovery train blank) was assembled and recovered according to the usual MM5 recovery procedures. The rinses and other components of the field recovery train blank (filter, XAD trap, and impinger solution) were submitted to Troika for dioxin/furan analysis. Analytical results for the proof train blank and field recovery train blank are presented in Section 8.3.1.3.

8.1.2 Procedural QC Activities/Manual Gas Sampling

Procedural QC activities during the manual gas sampling for dioxin/furan and HCl focused on:

- visual equipment inspections
- utilization of sample train blanks,
- ensuring the proper location and number of traverse points,
- conducting pre-test and post-test sample train leak checks,

TABLE 8-1. GLASSWARE PRECLEANING PROCEDURE

NOTE: USE DISPOSABLE GLOVES AND ADEQUATE VENTILATION

1. Soak all glassware in hot soapy water (Alconox^R) 50°C or higher.
2. Distilled/deionized H_2O rinse (X3).[a]
3. Chromerge^R rinse if glass, otherwise skip to 4.
4. High purity liquid chromatography grade H_2O rinse (X3).
5. Acetone rinse (X3), (pesticide grade).
6. Methylene chloride rinse (X3), (pesticide grade).
7. Cap glassware with clean glass plugs or methylene chloride rinsed aluminum foils.

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[a] (X3) = three times.

- maintaining proper temperatures at the filter housing, sorbent trap and impinger train,
- maintaining isokinetic sampling rates, and
- recording all data on preformatted field data sheets.

Unusual circumstances noted while carrying out the procedural QC activities are discussed below.

Due to the high temperatures encountered during this test series, the MM5 and HCl sampling trains were leak-checked by plugging the front of the cyclone bypass (upstream of the filter) rather than from the nozzle tip.

It was felt that there would be virtually no pressure drop in the probe and that with the low static pressure, even with a leak the sample would still be valid. At the end of the first test run when the outlet locations MM5 and HCl probes were disassembled, the glass liners were discovered to be cracked at the liner-to- nozzle swage connector. This problem was corrected and did not reoccur during the test series.

The oxygen and carbon dioxide values for the outlet location were determined using the continuous emissions monitoring data. It is felt that the CEM data more accurately reflect the actual concentrations in the stack during the test period than the integrated bag samples because overpressure in the GC carrier gas during analysis caused leakage into the system which biased the bag sample analysis.

In light of the Tier 4 Testing Program objectives, it is believed that the problems with the sampling locations will not create any significant deviation between the sampling results and true stack concentrations of emissions.

Results of the average isokinetics calculations for all the test runs are shown in Table 8-2. All the test runs fell within the required quality assurance value of 100 ±10 percent.

Initial, final and port change leak checks for the MM5 and HCl sample trains achieved the QA objectives for all of the test runs except the first MM5 and HCl run at the outlet location. None of the reported sample volumes required correction for sample train leakage. All leak check data are noted on the MM5 field data sheets.

TABLE 8-2. SUMMARY OF ISOKINETIC RESULTS

Run Number	MM5 Outlet[a] % Isokinetic	HCl Outlet[a] % Isokinetic	MM5 Inlet % Isokinetic
01	101.8	109.4	98.8
02	96.8	108.4	90.7
03	101.3	102.8	98.5

[a] The quality assurance objective for MM5 and HCl sampling was isokinetic of 100 ± 10 percent.

8.1.3 Sample Custody

Sample custody procedures used during this program emphasized documentation of the samples collected and the use of chain-of-custody records for samples transported to the laboratory for analysis. Steps taken to identify and document samples collected included labeling each sample with a unique alphanumeric code as shown in Figure 8-1 and logging the sample in a master logbook. All samples shipped to Troika or returned to Radian/RTP were also logged on chain-of-custody records that were signed by the field sample custodian upon shipment and also signed upon receipt at the laboratory. Sample shipment letters were sent with the samples detailing their analysis priority and are contained in Appendix F. Each sample container lid was individually sealed to ensure that samples were not tampered with. No evidence of loss of sample integrity was reported for samples collected at this site.

8.2 CONTINUOUS MONITORING/MOLECULAR WEIGHT DETERMINATION

Flue gas concentrations measured continuously at the stack location included O_2, CO, CO_2, THC, NO_x and SO_2. Quality control results for these analyses and molecular weight determination are discussed in this section. The molecular weight for the gases at the inlet location was determined by analyzing integrated bag samples of flue gas for O_2, CO_2, and N_2. Quality control for this analysis involved duplicate analyses of calibration gases immediately before and after sample analysis. Analysis of the calibration gases was repeated until two consecutive analyses within ±5 percent applied to duplicate analyses required for sample quantification. These criteria were met for all molecular weight determinations.

Drift check results for the continuously monitored flue gas parameters are summarized in Table 8-3. Data reduction was performed by assuming a linear drift of the instrument response over the test day based on drift checks at the beginning and end of the day. The CO_2 analyzer drift was 22.6% for Run 01 and 11.9% for run 02 while the target QC value was 10%. The drifts for the other analyzers were within the QC drift criteria.

The quality control standards for this program consisted of mid-range concentration standards that were intended for QC purposes and not for

011 - MM5 - AI- 01 - F

Plant designation (Plant 11)

Train Component

F - Filter
SM - XAD Module
PR - Probe Rinse
CR - Back-half/Coil Rinse
CD - Condensate
IR - Impinger Rinse

Sequential run or sample number for this plant (multiple samples collected at same time given A, B, C, etc. designation).

Sampling Location
AI - afterburner inlet
AO - afterburner outlet

Sample Type

MM5 - Modified Method 5
HCl - HCl train
O_2 - Oxygen
CO_2 - Carbon dioxide
CO - Carbon monoxide
NO_x - Nitrogen oxides
SO_2 - Sulfur dioxides
THC - Total hydrocarbon
IB - Integrated bag (Method 3)
S - Soils
AMB - Ambient air train
FOA - Furnace outlet bottom ash
FIA - Furnace inlet bottom ash
DR - Drum residues
DC - Drum coatings
RBL - Reagent blanks
BL - field blank
LAB/PR - laboratory proof blank

Figure 8-1. Alpha-numeric sampling code for Site DBR-A.

Table 8-3. Summary of Drift Check and Control Standard Results at Site 11.

			Drift Check			QC Standard			
Test Date	Test Run	Parameter	Input Concentration	Instrumen Drift,[a] %	Meets QC?[b]	Input Concentration	Output Concentration	Difference From Running Mean, %	Meets QC?[c]
8/6/85	01	O2	18.2% V	-0.07	Yes	11.9% V	11.9	-	Yes
8/7/85	02	O2	18.2% V	0.50	Yes	11.9% V	11.8	-0.42	Yes
8/8/85	03	O2	18.2% V	0.06	Yes	11.9% V	11.9	0.28	Yes
8/6/85	01	CO	5425 ppmV	9.85	Yes	2500 ppmV	2856.7	-	Yes
8/7/85	02	CO	5425 ppmV	12.20	No	2500 ppmV	2798	-1.04	Yes
8/8/85	03	CO	5425 ppmV	2.96	Yes	2500 ppmV	2779	-1.15	Yes
8/6/85	01	CO2	19.1% V	22.60	No	9.74% V	10.2	-	Yes
8/7/85	02	CO2	19.1% V	11.88	No	9.74% V	10.4	0.97	Yes
8/8/85	03	CO2	19.1% V	4.45	Yes	9.74% V	10.4	0.64	Yes
8/6/85	01	SO2	94.5 ppmV	5.28	Yes	19.6 ppmV	19.7	-	
8/7/85	02	SO2	94.5 ppmV	4.67	Yes	19.6 ppmV	23.4	0.58	Yes
8/8/85	03	SO2	94.5 ppmV	1.89	Yes	19.6 ppmV	20.5	-3.30	Yes
8/6/85	01	NOx	90 ppmv	9.44	Yes	21.0 ppmV	20.3	-	Yes
8/7/85	02	NOx	90 ppmv	2.29	Yes	21.0 ppmV	19.9	-1.00	Yes
8/8/85	03	NOx	90 ppmv	2.14	Yes	21.0 ppmV	19.6	-1.67	Yes
8/6/85	01	THC	90 ppmv	4.77	Yes	19.7 ppmV	20.8	-	-
8/7/85	02	THC	90 ppmv	4.00	Yes	19.7 ppmV	20.6	-0.48	-
8/8/85	03	THC	90 ppmv	1.27	Yes	19.7 ppmV	20.5	-0.65	Yes

a. Instrument drift is defined as the percent difference between the instrument response to the input concentration at the beginning and end of the test run.

b. QC criteria was instrument drift within +/- 10 percent.

c. QC criteria was output concentration within +/- 10 percent of the running mean concentration for this test site.

instrument calibration. The QC gases were analyzed immediately after calibration each day to provide data on day-to-day instrument variability. The acceptance criteria for the analysis of each QC standard was agreement within ±10 percent of the running mean value.

8.3 VALIDATION OF O_2 AND CO_2 DATA

The oxygen and carbon dioxide data collected during the test were validated as follows. The maximum percent of CO_2 possible in the flue gas was calculated assuming that all of the carbon is converted to CO_2 and based on the ultimate analysis of the fuel (carbon, hydrogen, sulfur, nitrogen and oxygen content).

As shown in Figure 8-2, the CEM test data were plotted on a graph of oxygen in flue gas versus carbon monoxide in flue gas. Then a line was drawn between the oxygen concentration in air (20.9 percent) and the maximum percent of CO_2 possible. Both the natural gas and the residues on the drums were sources of carbon. By assuming that all the carbon came from methane in the natural gas, the maximum percent CO_2 was estimated at 11.7.

The CEM data falls within a reasonable range and is considered valid. If the carbon content of the drum residues could be included, the line would be adjusted upward.

8.4 LABORATORY ANALYSES

QA/QC activities were carried out for dioxin/furan, precursor, and total chloride analyses performed in Site DBR-A samples. The dioxin/furan analyses of MM5 train samples, ash samples, and ambient XAD train samples performed by Troika are considered in Section 8.4.1; the precursor analyses of drum residue and coating samples performed by Radian/RTP are considered in Section 8.4.2; and the total chloride analyses of HCl train samples performed by Radian/Austin are considered in Section 8.4.3.

8.4.1 Dioxin/Furan Analyses

This section discusses the dioxin/furan analyses performed on samples from Site DBR-A. Analytical recoveries of labelled surrogate compounds spiked onto MM5 train samples, ash samples, and ambient XAD samples prior to extraction are reported in Section 8.4.1.1. Sample blank data are reported in Section 8.4.1.2.

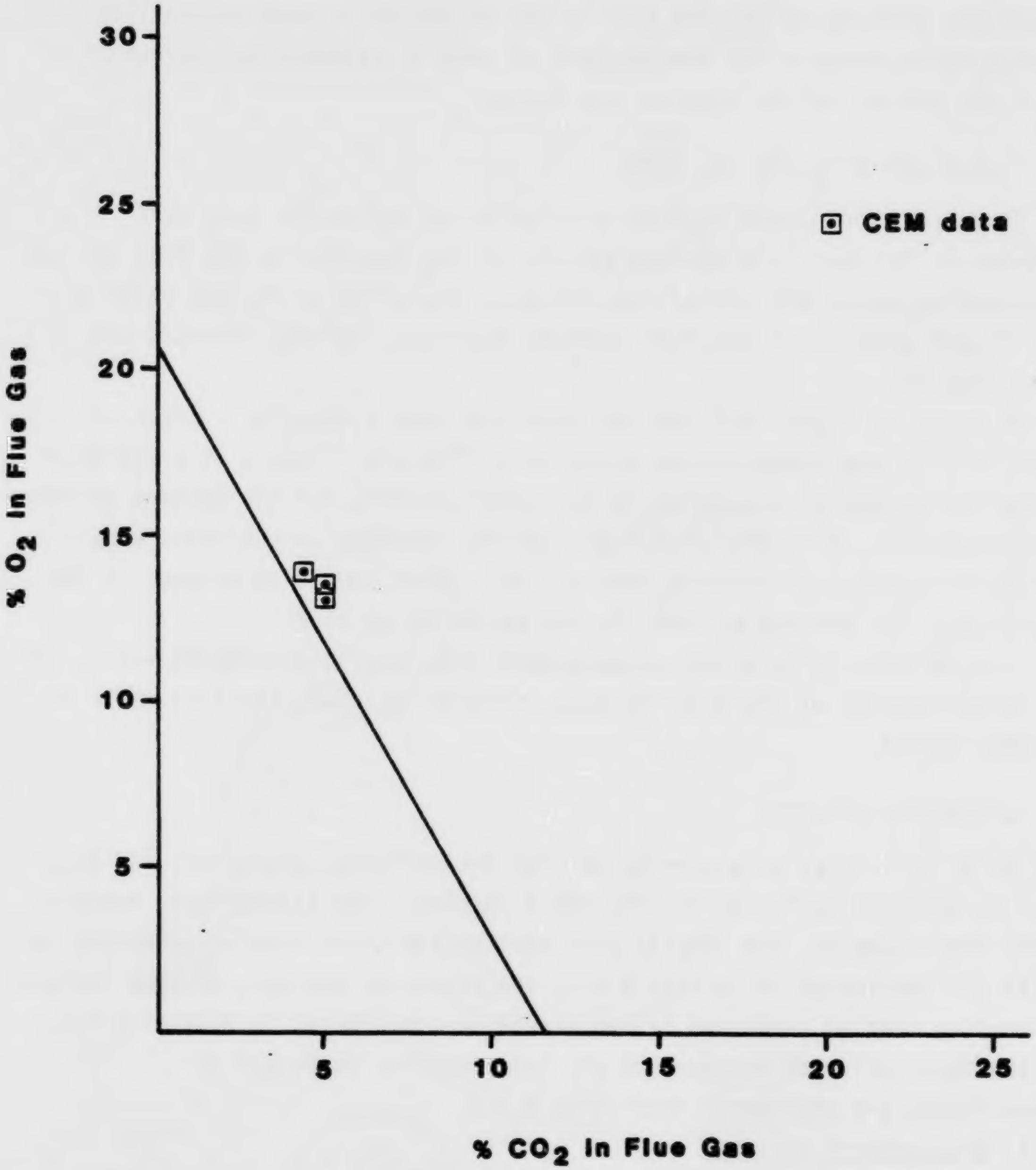

Figure 8-2. Validation of CEM, O$_2$ and CO$_2$ Data at Site 11.

TABLE 8-4. PERCENT SURROGATE RECOVERIES FOR SITE DBR-A DIOXIN/FURAN ANALYSES

Sample	$^{37}Cl_4$ TCDD	$^{13}C_{12}$ TCDD	$^{37}Cl_4$ Hepta-CDD	$^{13}C_{12}$ Octa-CDD
MM5 Train Samples				
Afterburner Inlet				
Run 01	84	66	NR	11
Run 02	76	68	NR	98
Run 03	92	106	26	28
Afterburner Outlet				
Run 01	94	100	45	40
Run 02	102	88	47	41
Run 03	94	96	52	42
Ambient XAD Train	102	100	42	47
Ash Samples				
Furnace Inlet				
Run 01	NS	61	NS	ND
Furnace Outlet				
Run 01	NS	50	NS	42
Run 02	NS	88	NS	ND

ND = None detected in sample extract.
NR = No recovery value reported by Troika.
NS = Surrogate compound not spiked into sample.

8.4.1.1 Surrogate Recoveries of the Test Samples

Table 8-4 presents the analytical recovery data reported by Troika for four isotopically labelled surrogate compounds spiked onto the primary MM5 train samples, ash samples, and ambient XAD train samples. Those samples consisting solely of solid components (i.e., ash, and ambient train XAD traps) were spiked with the $^{13}C_{12}$-TCDD and $^{13}C_{12}$-OCDD surrogates. Samples that consisted of both solid and liquid components (i.e., the primary MM5 trains samples) were spiked with all four of the surrogates. Surrogate recoveries for the MM5 train samples, ambient XAD train samples, and ash samples were fairly consistent between runs. Surrogate recoveries for the afterburner outlet MM5 samples and the ambient XAD train sample were all within the QA targets specified in the Tier 4 QAPP. For these samples recoveries of the labelled TCDD species ranged form 88 to 102 percent, and recoveries for the hepta- and octa-CDD species ranged from 40 to 52 percent. At the afterburner inlet, surrogate recoveries of the labelled TCDD species were within the Tier 4 QA targets of 50 to 120 percent, but recoveries of the labelled hepta- and octa-CDD species were not within the QA target of 40 to 120 percent. However, the Troika laboratory report indicated that sufficient amounts of the labelled octa-CDD surrogate was present for the analytical results to provide reasonably accurate estimates of minimum values for hepta- and octa-CDD's/CDF's at the afterburner inlet.

Surrogate recoveries for the ash samples did not satisfy the Tier 4 QA requirements. The Troika laboratory report indicated that some unknown type of contamination destroyed the GC resolution and the MS sensitivity for these samples.

8.4.1.2 Sample Blanks

Table 8-5 summarizes the analytical results reported by Troika for internal laboratory blanks, laboratory fortified quality control (QC) samples, and field recovery blank MM5 train samples. In general, the data show surrogate recoveries within the Tier 4 QA targets with values ranging from 40 to 104 percent. Comparison of the measured and spiked values for the laboratory fortified QC samples showed agreement to within ± 44 percent for all target species. Table 8-6 gives a comparison of the dioxin/furan analytical results for the field blank MM5 trains and the test run MM5 trains

TABLE 8-5. ANALYSIS RESULTS FOR QUALITY CONTROL SAMPLES

	Flue Gas Quality Control Samples				
		Fortified Laboratory QC Sample		Field Blank MM5 Train	
Compound	Laboratory Blank	Measured Value	True Value[a,b]	Inlet	Outlet
	Amount Detected (Nanograms per Sample)				
Dioxins					
2378 TCDD	ND	0.3	0.4 (-25)	ND	ND
Other TCDD	ND	ND	ND (0)	0.7	ND
Penta CDD	ND	ND	ND (0)	0.7	ND
Hexa CDD	ND	1.0	1.6 (-38)	1.6	ND
Hepta CDD	ND	2.9	2.4 (21)	2.6	ND
Octa CDD	0.1	3.1	3.2 (-3)	0.1	0.3
Furans					
2378 TCDF	ND	0.4	0.4 (0)	ND	ND
Other TCDF	ND	ND	ND (0)	4.7	ND
Penta CDF	ND	0.5	0.8 (-38)	3.6	ND
Hexa CDF	ND	0.9	1.6 (-44)	5.1	ND
Hepta CDF	ND	3.2	2.4 (33)	4.6	ND
Octa CDF	ND	3.1	3.2 (-3)	1.2	ND
	Surrogate Recoveries (Percent)				
$^{37}Cl_4$-TCDD	96	96	NA	72	80
$^{13}C_{12}$-TCDD	98	102	NA	72	88
$^{37}Cl_4$-Hepta CDD	43	41	NA	65	68
$^{13}C_{12}$-Octa CDD	42	40	NA	96	104

[a] True values represent the amounts of each homologue spiked into the laboratory fortified QC samples.

[b] Value shown in parenthesis is the percentage difference between the measured and the true value:

$$\% = \frac{\text{Measured Value - True Value}}{\text{True Value}} \times 100$$

ND = Not Detected

NA = Not Applicable

TCDD = Tetra-chlorinated dibenzo-p-dioxin

TABLE 8-6. FIELD BLANK DIOXIN/FURAN DATA FOR SITE DBR-A MM5 SAMPLES

Isomer/Homologue	Amount Detected, Nanograms per Train					
	Field Blank Value		Minimum Test Run Value		Percentage[a]	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Dioxins						
2378 TCDD	ND	ND	10.2	0.04	0	0
Other TCDD	0.7	ND	45.6	1.2	2	0
Penta CDD	0.7	ND	39.7	0.3	2	0
Hexa CDD	1.6	ND	24.4	0.6	7	0
Hepta CDD	2.6	ND	10.7	1.1	24	0
Octa CDD	1.0	0.3	9.0	1.1	9	27
Furans						
2378 TCDF	ND	ND	48.1	0.1	0	0
Other TCDF	4.7	ND	499	16.4	1	0
Penta CDF	3.6	ND	254	5.8	1	0
Hexa CDF	5.1	ND	46.9	2.9	11	0
Hepta CDF	4.6	ND	19.5	2.0	24	0
Octa CDF	1.2	ND	4.0	0.5	30	0

[a] Percentage shown is the ratio of the field blank value to the minimum test run value, expressed as a percentage.

at the afterburner inlet and outlet. At the afterburner outlet, only the octa-CDD homologue was detected in the field blank. The measured field blank value represented 27 percent of the minimum test run value. This indicates that there were no significant blanking problems at this location. The field blank at the afterburner inlet was not as clean as the field blank at the afterburner outlet. However, the field blank train values for individual homologues represented no more than 30 percent of the minimum test run values and in most cases was less than 10 percent of the minimum test run values. Overall, the field clean-up procedures were found to be adequate for this test site. Emissions data reported in Section 5.4 were not blank-corrected.

8.4.2 Precursor Analyses

Table 8-7 presents analytical recovery efficiencies for six isotopically labelled compounds used as surrogates for the target precursor analytes in the Site DBR-A drum residue and drum coating. The surrogate recovery values in Table 8-7 vary by sample type and by specific surrogate species. The overall ranges of surrogate recoveries for the different types of feed samples were 3 to 97 percent for drum residue samples and 8 to 81 percent for drum coating samples. These values are below the 50 percent objective stated in the Tier 4 QA Project Plan and are below those generally considered achievable when analyzing for similar compounds in water or from MM5 train components. There are no directly comparable surrogate recovery values reported in the literature for samples similar to the Site DBR-A feed materials.

There are several reasons for the comparatively low surrogate recoveries reported in the Tier 4 study for samples such as the Site DBR-A drum residues and coatings. First, the complex nature of the samples required extensive clean-up procedures prior to GC/MS analysis, which increased the potential for losses of the surrogate compounds (and analytes) during sample preparation. Second, large sample sizes (25 to 50 g) were required to increase method sensitivity for the target analytes and to ensure that representative portions of the samples were analyzed. Due to the high cost of labelled surrogates, it was not desirable to spike the large sample sizes with surrogates in proportion to that normally used for smaller samples. Supplemental in-house laboratory studies showed that when sample size was restricted to 1 g and the amount of surrogate spiked was held fixed, surrogate recoveries improved and

TABLE 8-7. PERCENT SURROGATE RECOVERIES FOR SITE DBR-A FEED SAMPLES

Surrogate Compound	Percent Surrogate Recovery					
	Drum Residue Feed Samples				Drum Coating Feed Sample	
	Run 01	Run 02	Run 03	Average	Run[a]	Average
d_4-dichlorobenzene	24	25	37	29	8, 10	9
bromobiphenyl	38	63	76	59	18, 29	24
2',5,5' tetrabromobiphenyl	37	67	97	67	13, 20	17
d_6-phenol	6	15	26	16	17, 9	13
d_4-2-chlorophenol	10	36	44	30	81, 45	63
$^{13}C_6$-pentachlorophenol	3	16	20	13	8, 15	12

---

[a] Only one drum coating sample was collected. Duplicate analyses was performed on the sample.

were directly comparable with those obtained by Tiernan and co-workers for municipal incinerator feed materials. Surrogate recoveries for Tier 4 samples and the results for small sample sizes are further discussed in the Tier 4 Engineering Analysis Report.

In spite of the relatively low surrogate recovery values for some of the feed samples, the resulting analytical sensitivity for the target analytes was considered acceptable for the purpose of this study. The instrumental detection limit ranged from about 100 to 500 picograms on-column for the 1 microliter of final extract injected into the GC/MS. At a method recovery efficiency of 100 percent for a 50 gram solid sample cleaned up to a final extract volume of 1 milliliter, the overall analytical sensitivity would be approximately 2 to 10 ppb in the solid sample. For samples such as the drum residues with surrogate recoveries as low as 3 percent, the overall analytical sensitivity of the method would still be 70 to 330 ppb. Thus, even in a worst-case situation the analytical procedures used provide information on the precursor content of the feed samples down to the ppm level.

8.4.3 Total Chloride Analyses

Total chloride analyses were performed by Radian/Austin on the HCl train samples. QA/QC activities included total chloride analysis of field recovery blank HCl train samples, total chloride analysis of an aliquot of the NaOH solution used in the sample train impingers, and duplicate total chloride analyses of five audit samples. Very low levels of chlorides were detected in the field recovery blank trian samples and no chlorides were detected in the aliquot of the NaOH solution analyzed. Table 8-8 shows the results of the duplicate ion chromatograph analyses of the audit samples. Duplicate analyses were in very close agreement, and the analytical results were within 5.3 percent of the audit concentrations.

TABLE 8-8. RESULTS OF DUPLICATE ANALYSES OF CHLORIDE AUDIT SAMPLES

Site #	Field #	Expected from Audit	Blank Corrected Total Mg	Error Percent
11-RAS-HCL-6	1	25.000	25.6/25.5	+ 2.2
11-RAS-HCL-7	2	25.000	25.4/25.5	+ 1.8
11-RAS HCL-8	3	100.00	101/101	+ 1
11-RAS-HCL-9	4	1000.0	1020/1030	+ 2.5
11-RAS-HCL-10	5	500.0	527/526	+ 5.3

APPENDICES

Appendix A - Field Results
  A-1 - Definition of Terms and Sample Calculation for MM5 Calculations
  A-2 - Furnace Outlet Exhaust Duct MM5 Calculations and Results
  A-3 - Afterburner Outlet Exhaust Stack MM5 Calculations and Results
  A-4 - Afterburner Outlet Exhaust Stack HCL Calculations and Results
  A-5 - Ambient Air Calculations and Results
Appendix B - Process Monitoring Data
Appendix C - CEM Data
Appendix D - Sample Shipping Letters
Appendix E - Dioxin/Furan Analytical Data
Appendix F - Run-Specific Dioxin/Furan Emissions Data
  F-1 - Furnace Outlet Exhaust Duct Run-Specific Dioxin/Furan Emissions Data (As-measured Concentrations)
  F-2 - Afterburner Outlet Stack Run Specific Dioxin/Furan Emissions Data (As-measured Concentrations)
  F-3 - Furnace Outlet Exhaust Duct Run-Specific Dioxin/Furan Emissions Data (Concentrations Corrected to 3% Oxygen)
  F-4 - Afterburner Outlet Stack Run Specific Dioxin/Furan Emissions Data (Concentrations Corrected to 3% Oxygen)
Appendix G - Risk Modeling Input Parameters (Afterburner Outlet)
Appendix H - Error Analysis of Control Device Efficiency Calculations

APPENDIX A-1

EXAMPLE CALCULATIONS AND DEFINITION OF TERMS

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RADIAN SOURCE TEST
EPA METHODS 2-5
DEFINITION OF TERMS

PARAMETER	DEFINITION
Tt(min.)	TOTAL SAMPLING TIME
Dn(in.)	SAMPLING NOZZLE DIAMETER
Ps(in.H2O)	ABSOLUTE STACK STATIC GAS PRESSURE
Vm(cu.ft.)	ABSOLUTE VOLUME OF GAS SAMPLE MEASURED BY DGM
Vw(gm.)	TOTAL STACK MOISTURE COLLECTED
Pm(in.H2O)	AVERAGE STATIC PRESSURE OF DGM
Tm(F)	AVERAGE TEMPERATURE OF DGM
Pb(in.Hg.)	BAROMETRIC PRESSURE
% CO2	CARBON DIOXIDE CONTENT OF STACK GAS
% O2	OXYGEN CONTENT OF STACK GAS
% N2	NITROGEN CONTENT OF STACK GAS
SQR(DELPS)	AVE. SQ. ROOT OF S-PITOT DIFF. PRESSURE-TEMP. PRODUCTS
As(sq.in.)	CROSS-SECTIONAL AREA OF STACK(DUCT)
Ts(F)	TEMPERATURE OF STACK
Vm(dscf)	STANDARD VOLUME OF GAS SAMPLED ,Vm(std),AS DRY STD. CF
Vm(dscm)	STANDARD VOLUME OF GAS SAMPLED,Vm(std),AS DRY STD. CM
Vw gas(scf)	VOLUME OF WATER VAPOR IN GAS SAMPLE,STD
% moisture	WATER VAPOR COMPOSITION OF STACK GAS
Md	PROPORTION, BY VOLUME,OF DRY GAS IN GAS SAMPLE
MWd	MOLECULAR WEIGHT OF STACK GAS,DRY BASIS LB/LB-MOLE
MW	MOLECULAR WEIGHT OF STACK GAS,WET BASIC LB/LB-MOLE
Vs(fpm)	AVERAGE STACK GAS VELOCITY
Flow(acfm)	AVERAGE STACK GAS FLOW RATE(ACTUAL STACK COND.)
Flow(acmm)	AVERAGE STACK GAS FLOW RATE(ACTUAL STACK COND.)
Flow(dscfm)	AVERAGE STACK GAS VOLUMETRIC FLOW RATE(DRY BASIS)
Flow(dscmm)	AVERAGE STACK GAS VOLUMETRIC FLOW RATE(DRY BASIS)
% I	PERCENT ISOKINETIC
% EA	PERCENT EXCESS AIR IN STACK GAS
DGM	DRY GAS METER
Y	DRY GAS METER CORRECTION FACTOR
Pg	STACK STATIC GAS PRESSURE
Cp	PITOT COEFFICIENT
dH	ORIFICE PLATE DIFF. PRESS. VALUE
dP	PITOT DIFF. PRESS. VALUE
*** EPA STANDARD CONDITIONS	Temperature = 68 deg-F (528 deg-R) Pressure = 29.92 in. Hg.

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RADIAN SOURCE TEST
EPA METHOD 2--5
SAMPLE CALCULATION

```
PLANT                  : DIOXIN SITE #11
PLANT SITE             : CHARLOTTE , NORTH CAROLINA
SAMPLING LOCATION      : AFTERBURNER OUTLET
TEST #                 : 11-MM5-AO-01
DATE                   : 08/06/85
TEST PERIOD            : 0927-1127  1328-1528

1) Volume of dry gas sampled at standard conditions (68 deg-F ,29.92 in. Hg).

               Y x Vm x [T(std) + 460] x [Pb +(Pm/13.6)]
    Vm(std) = ------------------------------------------
                    P(std) x (Tm + 460)

               1 x 133.44  x 528 x [ 29.3  + ( .96 /13.6)]
    Vm(std) = ---------------------------------------------
                   29.92    x ( 100.3  + 460)

    Vm(std) =  123.438dscf

2) Volume of water vapor at standard conditions:

    Vw(gas) =  0.04715 cf/gm x W(l) gm

    Vw(gas) =  0.04715 x  258.9   =  12.207 scf

3) Percent Moisture in stack gas :

               100 x Vw(gas)
    %M = --------------------
           Vm(std)   + Vw(gas)

               100 x  12.207
    %M = -------------------- =   9.00 %
            123.438 +   12.207

4) Mole fraction of dry stack gas :

               100 -    %M           100 -   9.00
    Md   =     ------------      = ------------ =  .9100071
                   100                  100
```

SAMPLE CALCULATION
PAGE TWO

5) Average Molecular Weight of DRY stack gas :

MWd = (.44 x %CO2) + (.32 x %O2) + (.28 x %N2)

MWd = (.44 x 5) + (.32 x 13.2) + (.28 x 81.8) = 29.328

6) Average Molecular Weight of wet stack gas :

MW = MWd x Md + 18(1 - Md)

MW = 29.328 x .9100071 + 18(1 - .9100071) = 28.30856

7) Stack gas velocity in feet-per-minute (fpm) at stack conditions :

Vs = KpxCp x [SQRT (dP)]{ave} x SQRT [Ts {avg}] x SQRT [1/(PsxMW)] x 60sec/min

Vs = 85.49 x .84 x 60 x 22.42955 x SQRT[1/(29.27794 X 28.30856)]

Vs = 3356.891 FPM

8) Average stack gas dry volumetric flow rate (DSCFM) :

$$Qsd = \frac{Vs \times As \times Md \times T(std) \times Ps}{144\ cu.in./cu.ft. \times (Ts + 460) \times P(std)}$$

$$Qsd = \frac{3356.891 \times 1017.878 \times .9100071 \times 528 \times 29.27794}{144 \times 1755.167 \times 29.92}$$

Qsd = 6356.377 dscfm

SAMPLE CALCULATION
PAGE THREE

```
9)Isokinetic sampling rate (%) :

        Dimensional Constant C = K4 x 60 x 144 x [1 / (Pi  /4)]
        K4 = .0945 FOR ENGLISH UNITS

                    C x Vm(std) x (Ts + 460)
        I% =      --------------------------------------
                  Vs x Tt x Ps x Md x (Dn)^2

                    1039.574 x 123.4384 x 1755.167
        I% = -------------------------------------------
               3356.891 x 240 x 29.27794 x .9100071 x( .321 )^2

        I% =  101.8312

 10) Excess air (%) :

                    100 x %O2             100 x 13.2
        EA =      --------------- = ----------------
                  (.264 x %N2) - %O2  (.264 x 81.8 ) - 13.2

        EA =         157.23

 11) Particulate Concentration :

        Cs = ( grams part.) / Vm(std) =  0 / 123.4384

        Cs =        0.0000000 Grams/DSCF

                    T(std) x Md x Ps x Cs
        Ca =      --------------------------------
                    P(std) x Ts

                    528 x .9100071  x 29.27794  x       0.0000000
        Ca =      --------------------------------
                    29.92      x      1755.167

        Ca =              0.0000000 Grams/ACF

        LBS/HR =  Cs x 0.002205 x Qsd x 60

        LBS/HR =          0.0000000x 0.002205 x  6356.4 x 60

        LBS/HR = 0

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```

APPENDIX A-2

FURNACE OUTLET EXHAUST DUCT MM5 CALCULATIONS AND RESULTS

```
        RADIAN SOURCE TEST
        EPA METHOD 2-5
         (RAW DATA)
     PLANT                 : DIOXIN SITE #11
     PLANT SITE            :
     SAMPLING LOCATION     : INCINERATOR OUTLET/AFTERBURNER INLET
     TEST #                : 11-MM5-AI-01
     DATE                  : 08/06/85
     TEST PERIOD           : 0922-1122  1330-1530


   PARAMETER                                 VALUE
   ---------                                 -----

   Sampling time (min.)                       240
   Barometric Pressure (in.Hg)                29.3
   Sampling nozzle diameter (in.)             .373
   Meter Volume (cu.ft.)                      163.771
   Meter Pressure (in.H2O)                    1.56
   Meter Temperature (F)                      130.8
   Stack dimension (sq.in.)                   706.86
   Stack Static Pressure (in.H2O)            -.45
   Stack Moisture Collected (gm)              386.6
   Absolute stack pressure(in Hg)             29.26691
   Average stack temperature (F)              1314.277
   Percent CO2                                3.7
   Percent O2                                 15.9
   Percent N2                                 80.4
   Delps Subroutine result                    20.67903
   DGM Factor                                 1.007
   Pitot Constant                             .84
```

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```
     RADIAN SOURCE TEST
     EPA METHODS 2-5
     FINAL RESULTS
PLANT                  : DIOXIN SITE #11
PLANT SITE             :
SAMPLING LOCATION      : INCINERATOR OUTLET/AFTERBURNER INLET
TEST #                 : 11-MM5-AI-01
DATE                   : 08/06/85
TEST PERIOD            : 0922-1122  1330-1530

    PARAMETER                        RESULT
    ---------                        ------

    Vm(dscf)                          144.8982
    Vm(dscm)                          4.103516
    Vw gas(scf)                       18.22819
    Vw gas (scm)                      .5162224
    % moisture                        11.17428
    Md                                .8882572
    MWd                               29.228
    MW                                27.97335
    Vs(fpm)                           3113.978
    Vs (mpm)                          949.3835
    Flow(acfm)                        15285.74
    Flow(acmm)                        432.8921
    Flow(dscfm)                       3952.328
    Flow(dscmm)                       111.9299
    % I                               98.87349
    % EA                              298.5578




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```

```
   RADIAN SOURCE TEST
   EPA METHOD 2-5
   (RAW DATA)
 PLANT                 : DIOXIN SITE #11
 PLANT SITE            :
 SAMPLING LOCATION     : INCINERATOR OUTLET/AFTERBURNER INLET
 TEST #                : 11-MM5-AI-02
 DATE                  : 08/07/85
 TEST PERIOD           : 0927-1122  1320-1415  1425-1530

PARAMETER                                 VALUE
---------                                 -----

Sampling time (min.)                       240
Barometric Pressure (in.Hg)                29.24
Sampling nozzle diameter (in.)             .373
Meter Volume (cu.ft.)                      173.195
Meter Pressure (in.H2O)                    1.8
Meter Temperature (F)                      130.4
Stack dimension (sq.in.)                   706.86
Stack Static Pressure (in.H2O)            -.45
Stack Moisture Collected (gm)              333.5
Absolute stack pressure(in Hg)             29.20691
Average stack temperature (F)              1173.729
Percent CO2                                6.4
Percent O2                                 18
Percent N2                                 75.6
Delps Subroutine result                    21.76099
DGM Factor                                 1.007
Pitot Constant                             .84
```

```
   RADIAN SOURCE TEST
   EPA METHODS 2-5
   FINAL RESULTS
PLANT                : DIOXIN SITE #11
PLANT SITE           :
SAMPLING LOCATION    : INCINERATOR OUTLET/AFTERBURNER INLET
TEST #               : 11-MM5-AI-02
DATE                 : 08/07/85
TEST PERIOD          : 0922=1122  1320 1415  1425-1530


    PARAMETER                  RESULT
    ---------                  -----

    Vm(dscf)                   153.1192
    Vm(dscm)                   4.336334
    Vw gas(scf)                15.72453
    Vw gas (scm)               .4453186
    % moisture                 9.313066
    Md                         .9068694
    MWd                        29.744
    MW                         28.65027
    Vs(fpm)                    3241.286
    Vs (mpm)                   988.1968
    Flow(acfm)                 15910.66
    Flow(acmm)                 450.5899
    Flow(dscfm)                4552.09
    Flow(dscmm)                128.9152
    % I                        90.71699
    % EA                       919.1182


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```

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```
        RADIAN  SOURCE  TEST
        EPA  METHOD  2-5
        (RAW  DATA)
     PLANT                 : DIOXIN SITE #11
     PLANT SITE            :
     SAMPLING LOCATION     : INCINERATOR OUTLET/AFTERBURNER INLET
     TEST #                : 11-MM5-AI-03
     DATE                  : 08/08/85
     TEST PERIOD           : 0900-1100  1320-1520

   PARAMETER                                  VALUE
   ---------                                  -----

   Sampling time (min.)                        240
   Barometric Pressure (in.Hg)                 29.13
   Sampling nozzle diameter (in.)              .373
   Meter Volume (cu.ft.)                       150.937
   Meter Pressure (in.H2O)                     1.36
   Meter Temperature (F)                       121
   Stack dimension (sq.in.)                    706.86
   Stack Static Pressure (in.H2O)             -.45
   Stack Moisture Collected (gm)               375.8
   Absolute stack pressure(in Hg)              29.09691
   Average stack temperature (F)               1294.917
   Percent CO2                                 4
   Percent O2                                  17.6
   Percent N2                                  78.4
   Delps Subroutine result                     19.27099
   DGM Factor                                  1.007
   Pitot Constant                              .84
```

```
  RADIAN SOURCE TEST
  EPA METHODS 2-5
  FINAL RESULTS
PLANT                : DIOXIN SITE #11
PLANT SITE           :
SAMPLING LOCATION    : INCINERATOR OUTLET/AFTERBURNER INLET
TEST #               : 11-MM5-AI-03
DATE                 : 08/08/85
TEST PERIOD          : 0900-1100  1320-1520

     PARAMETER                      RESULT
     ---------                      ------

     Vm(dscf)                        134.943
     Vm(dscm)                        3.821584
     Vw gas(scf)                     17.71897
     Vw gas (scm)                    .5018012
     % moisture                      11.60667
     Md                              .8839332
     MWd                             29.344
     MW                              28.02734
     Vs(fpm)                         2907.606
     Vs (mpm)                        886.4653
     Flow(acfm)                      14272.71
     Flow(acmm)                      404.2032
     Flow(dscfm)                     3691.379
     Flow(dscmm)                     104.5398
     % I                             98.58971
     % EA                            568.182
```

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```
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```

APPENDIX A-3

AFTERBURNER OUTLET EXHAUST STACK MM5 CALCULATIONS AND RESULTS

```
        RADIAN SOURCE TEST
        EPA METHOD 2-5
        (RAW DATA)
   PLANT                    : DIOXIN SITE #11
   PLANT SITE               :
   SAMPLING LOCATION        : AFTERBURNER OUTLET
   TEST #                   : 11-MM5-A0-01
   DATE                     : 08/06/85
   TEST PERIOD              : 0927-1127  1328-1528


PARAMETER                                VALUE
---------                                -----

Sampling time (min.)                      240
Barometric Pressure (in.Hg)               29.3
Sampling nozzle diameter (in.)            .321
Meter Volume (cu.ft.)                     133.44
Meter Pressure (in.H2O)                   .96
Meter Temperature (F)                     100.3
Stack dimension (sq.in.)                  1017.878
Stack Static Pressure (in.H2O)           -.3
Stack Moisture Collected (gm)             258.9
Absolute stack pressure(in Hg)            29.27794
Average stack temperature (F)             1295.167
Percent CO2                               5
Percent O2                                13.2
Percent N2                                81.8
Delps Subroutine result                   22.42955
DGM Factor                                1
Pitot Constant                            .84
```

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```
  RADIAN SOURCE TEST
  EPA METHODS 2-5
  FINAL RESULTS
PLANT                : DIOXIN SITE #11
PLANT SITE           :
SAMPLING LOCATION    : AFTERBURNER OUTLET
TEST #               : 11-MM5-AO-01
DATE                 : 08/06/85
TEST PERIOD          : 0927-1127  1328-1528

   PARAMETER                     RESULT
   ---------                     ------

   Vm(dscf)                       123.4384
   Vm(dscm)                       3.495776
   Vw gas(scf)                    12.20714
   Vw gas (scm)                   .3457061
   % moisture                     8.999289
   Md                             .9100071
   MWd                            29.328
   MW                             28.30856
   Vs(fpm)                        3356.891
   Vs (mpm)                       1023.442
   Flow(acfm)                     23728.51
   Flow(acmm)                     671.9913
   Flow(dscfm)                    6356.377
   Flow(dscmm)                    180.0126
   % I                            101.8312
   % EA                           157.2327




                                                 Program Revision:1/16/84
```

```
     RADIAN  SOURCE  TEST
     EPA  METHOD  2-5
      (RAW  DATA)
   PLANT                : DIOXIN SITE #11
   PLANT SITE           :
   SAMPLING LOCATION    : AFTERBURNER OUTLET
   TEST #               : 11-MM5-AO-02
   DATE                 : 08/07/85
   TEST PERIOD          : 0924-1124  1320-1416  1429-1533

PARAMETER                              VALUE
---------                              -----

Sampling time (min.)                    240
Barometric Pressure (in.Hg)             29.24
Sampling nozzle diameter (in.)          .321
Meter Volume (cu.ft.)                   139.45
Meter Pressure (in.H2O)                 1.1
Meter Temperature (F)                   102.5
Stack dimension (sq.in.)                1017.878
Stack Static Pressure (in.H2O)         -.3
Stack Moisture Collected (gm)           285.5
Absolute stack pressure(in Hg)          29.21794
Average stack temperature (F)           1244.061
Percent CO2                             4.7
Percent O2                              13.9
Percent N2                              81.4
Delps Subroutine result                 23.92332
DGM Factor                              1
Pitot Constant                          .84
```

```
   RADIAN  SOURCE  TEST
   EPA  METHODS  2-5
   FINAL  RESULTS
PLANT                  : DIOXIN SITE #11
PLANT SITE             :
SAMPLING LOCATION      : AFTERBURNER OUTLET
TEST #                 : 11-MM5-AO-02
DATE                   : 08/07/85
TEST PERIOD            : 0924-1124  1320-1416  1429-1533


    PARAMETER                       RESULT
    ---------                       ------

    Vm(dscf)                         128.276
    Vm(dscm)                         3.632776
    Vw gas(scf)                      13.46133
    Vw gas (scm)                     .3812247
    % moisture                       9.497376
    Md                               .9050262
    MWd                              29.308
    MW                               28.23404
    Vs(fpm)                          3588.857
    Vs (mpm)                         1094.164
    Flow(acfm)                       25368.18
    Flow(acmm)                       718.4268
    Flow(dscfm)                      6946.841
    Flow(dscmm)                      196.7345
    % I                              96.82732
    % EA                             183.1453




                                                   Program Revision:1/16/84
   RADIAN  SOURCE  TEST
   EPA  METHOD  2-5
   (RAW  DATA)
 PLANT                  : DIOXIN SITE #11
 PLANT SITE             :
 SAMPLING LOCATION      : AFTERBURNER OUTLET
 TEST #                 : 11-MM5-AO-03
 DATE                   : 08/08/85
 TEST PERIOD            : 0858-1058  1317-1517

PARAMETER                                      VALUE
---------                                      -----

Sampling time (min.)                            240
Barometric Pressure (in.Hg)                     29.13
Sampling nozzle diameter (in.)                  .321
Meter Volume (cu.ft.)                           150.87
Meter Pressure (in.H2O)                         1.23
Meter Temperature (F)                           107.9
Stack dimension (sq.in.)                        1017.878
Stack Static Pressure (in.H2O)                 -.3
Stack Moisture Collected (gm)                   339.1
Absolute stack pressure(in Hg)                  29.10794
Average stack temperature (F)                   1250.875
Percent CO2                                     5
Percent O2                                      13.4
Percent N2                                      81.6
Delps Subroutine result                         24.79661
DGM Factor                                      1
Pitot Constant                                  .84
```

```
  RADIAN SOURCE TEST
  EPA METHODS 2-5
  FINAL RESULTS
PLANT                  : DIOXIN SITE #11
PLANT SITE             :
SAMPLING LOCATION      : AFTERBURNER OUTLET
TEST #                 : 11-MM5-AO-03
DATE                   : 08/08/85
TEST PERIOD            : 0858-1058  1317-1517

   PARAMETER                   RESULT
   ---------                   ------

   Vm(dscf)                     136.9904
   Vm(dscm)                     3.879567
   Vw gas(scf)                  15.98857
   Vw gas (scm)                 .4527962
   % moisture                   10.45148
   Md                           .8954852
   MWd                          29.336
   MW                           28.15122
   Vs(fpm)                      3732.362
   Vs (mpm)                     1137.915
   Flow(acfm)                   26382.56
   Flow(acmm)                   747.1541
   Flow(dscfm)                  7093.178
   Flow(dscmm)                  200.8788
   % I                          101.2719
   % EA                         164.5706




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```

APPENDIX A-4

AFTERBURNER OUTLET EXHAUST STACK HCL CALCULATIONS AND RESULTS

RADIAN SOURCE TEST
EPA METHOD 2-5
(RAW DATA)

PLANT : DIOXIN SITE #11
PLANT SITE :
SAMPLING LOCATION : AFTERBURNER OUTLET
TEST # : 11-HCL-AO-01
DATE : 08/06/85
TEST PERIOD : 1015-1125 1335-1445

PARAMETER	VALUE
Sampling time (min.)	140
Barometric Pressure (in.Hg)	29.3
Sampling nozzle diameter (in.)	.308
Meter Volume (cu.ft.)	83.447
Meter Pressure (in.H2O)	1.04
Meter Temperature (F)	96.5
Stack dimension (sq.in.)	1017.878
Stack Static Pressure (in.H2O)	-.3
Stack Moisture Collected (gm)	167.7
Absolute stack pressure(in Hg)	29.27794
Average stack temperature (F)	1320.571
Percent CO2	5
Percent O2	13.2
Percent N2	81.8
Delps Subroutine result	24.872
DGM Factor	1
Pitot Constant	.84

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```
RADIAN SOURCE TEST
EPA METHODS 2-5
FINAL RESULTS
PLANT                 : DIOXIN SITE #11
PLANT SITE            :
SAMPLING LOCATION     : AFTERBURNER OUTLET
TEST #                : 11-HCL-AO-01
DATE                  : 08/06/85
TEST PERIOD           : 1015-1125  1335-1445

   PARAMETER                     RESULT
   ---------                     ------

   Vm(dscf)                      77.73516
   Vm(dscm)                      2.20146
   Vw gas(scf)                   7.907055
   Vw gas (scm)                  .2239278
   % moisture                    9.232661
   Md                            .9076734
   MWd                           29.328
   MW                            28.28213
   Vs(fpm)                       3724.177
   Vs (mpm)                      1135.42
   Flow(acfm)                    26324.71
   Flow(acmm)                    745.5156
   Flow(dscfm)                   6933.407
   Flow(dscmm)                   196.3541
   % I                           109.4719
   % EA                          157.2327


                                        Program Revision:1/16/84
   RADIAN SOURCE TEST
   EPA METHOD 2-5
   (RAW DATA)
  PLANT                  : DIOXIN SITE #11
  PLANT SITE             :
  SAMPLING LOCATION      : AFTERBURNER OUTLET
  TEST #                 : 11-HCL-AO-02
  DATE                   : 08/07/85
  TEST PERIOD            : 0947-1057  1327-1409  1434-1502

PARAMETER                               VALUE
---------                               -----

Sampling time (min.)                     140
Barometric Pressure (in.Hg)              29.24
Sampling nozzle diameter (in.)           .308
Meter Volume (cu.ft.)                    89.169
Meter Pressure (in.H2O)                  1.1
Meter Temperature (F)                    99
Stack dimension (sq.in.)                 1017.878
Stack Static Pressure (in.H2O)          -.3
Stack Moisture Collected (gm)            188.3
Absolute stack pressure(in Hg)           29.21794
Average stack temperature (F)            1303.353
Percent CO2                              4.7
Percent O2                               13.9
Percent N2                               81.4
Delps Subroutine result                  26.53306
DGM Factor                               1
Pitot Constant                           .84
```

```
    RADIAN SOURCE TEST
    EPA METHODS 2-5
    FINAL RESULTS
PLANT                  : DIOXIN SITE #11
PLANT SITE             :
SAMPLING LOCATION      : AFTERBURNER OUTLET
TEST #                 : 11-HCL-AO-02
DATE                   : 08/07/85
TEST PERIOD            : 0947-1057  1327-1409  1434-1502

    PARAMETER                    RESULT
    ---------                    ------

    Vm(dscf)                      82.53752
    Vm(dscm)                      2.337463
    Vw gas(scf)                   8.878346
    Vw gas (scm)                  .2514348
    % moisture                    9.71204
    Md                            .9028796
    MWd                           29.308
    MW                            28.20976
    Vs(fpm)                       3982.068
    Vs (mpm)                      1214.045
    Flow(acfm)                    28147.64
    Flow(acmm)                    797.1411
    Flow(dscfm)                   7431.124
    Flow(dscmm)                   210.4494
    % I                           108.4498
    % EA                          183.1453



                                         Program Revision:1/16/84
    RADIAN SOURCE TEST
    EPA METHOD 2-5
    (RAW DATA)
  PLANT                  : DIOXIN SITE #11
  PLANT SITE             :
  SAMPLING LOCATION      : AFTERBURNER OUTLET
  TEST #                 : 11-HCL-AO-03
  DATE                   : 08/08/85
  TEST PERIOD            : 0857-1007  1315-1425


PARAMETER                                VALUE
---------                                -----

Sampling time (min.)                      140
Barometric Pressure (in.Hg)               29.13
Sampling nozzle diameter (in.)            .308
Meter Volume (cu.ft.)                     79.18
Meter Pressure (in.H2O)                   .99
Meter Temperature (F)                     95.4
Stack dimension (sq.in.)                  1017.878
Stack Static Pressure (in.H2O)           -.3
Stack Moisture Collected (gm)             185.1
Absolute stack pressure(in Hg)            29.10794
Average stack temperature (F)             1319.067
Percent CO2                               5
Percent O2                                13.4
Percent N2                                81.6
Delps Subroutine result                   25.38702
DGM Factor                                1
Pitot Constant                            .84
```

```
   RADIAN SOURCE TEST
   EPA METHODS 2-5
   FINAL RESULTS
PLANT                    : DIOXIN SITE #11
PLANT SITE
SAMPLING LOCATION        : AFTERBURNER OUTLET
TEST #                   : 11-HCL-AC-03
DATE                     : 08/08/85
TEST PERIOD              : 0857-1007  1315-1425

   PARAMETER                        RESULT
   ---------                        ------

   Vm(dscf)                          73.46937
   Vm(dscm)                          2.080653
   Vw gas(scf)                       8.727466
   Vw gas (scm)                      .2471618
   % moisture                        10.61777
   Md                                .8938223
   MWd                               29.336
   MW                                28.13237
   Vs(fpm)                           3822.511
   Vs (mpm)                          1165.4
   Flow(acfm)                        27019.79
   Flow(acmm)                        765.2005
   Flow(dscfm)                       6973.08
   Flow(dscmm)                       197.4776
   % I                               102.8759
   % EA                              164.5706




                                           Program Revision:1/16/84
```

APPENDIX A-5

AMBIENT AIR CALCULATIONS AND RESULTS

```
         RADIAN  SOURCE  TEST
         EPA  METHOD  2-5
          (RAW  DATA)
       PLANT                  : DIOXIN SITE #11
       PLANT SITE             :
       SAMPLING LOCATION      : AMBIENT BY INCINERATOR
       TEST #                 : 11-AMB-B
       DATE                   : 8/6-8/85
       TEST PERIOD            :
(0925-1532)  (0840-1602)  (0845-1120/1145-1522)

      PARAMETER                                 VALUE
      ---------                                 -----

      Sampling time (min.)                       1181
      Barometric Pressure (in.Hg)                29.2
      Sampling nozzle diameter (in.)
      Meter Volume (cu.ft.)                      953.8
      Meter Pressure (in.H2O)                    .6
      Meter Temperature (F)                      113.1
      Stack dimension (sq.in.)
      Stack Static Pressure (in.H2O)
      Stack Moisture Collected (gm)              175.8
      Absolute stack pressure(in Hg)
      Average stack temperature (F)              90
      Percent CO2                                .001
      Percent O2                                 21
      Percent N2                                 79
      Delps Subroutine result
      DGM Factor                                  .999
      Pitot Constant
```

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```
            RADIAN SOURCE TEST
            EPA METHODS 2-5
            FINAL RESULTS
         PLANT                 : DIOXIN SITE #11
         PLANT SITE            :
         SAMPLING LOCATION     : AMBIENT BY INCINERATOR
         TEST #                : 11-AMB-A
         DATE                  : 8/6-8/85
         TEST PERIOD           :
(0925-1532)  (0840-1600)  (0845-1120/1145-1522)


            PARAMETER                    RESULT
            ---------                    ------

            Vm(dscf)                      476.8013
            Vm(dscm)                      13.50301
            Vw gas(scf)                   7.65716
            Vw gas (scm)                  .2168508
            %-moisture                    1.580561
            Md                            .9841944
            MWd                           28.84044
            MW                            28.6691










                                       Program Revision:1 16 84
```

```
          RADIAN  SOURCE  TEST
          EPA  METHOD  2-5
          (RAW  DATA)
        PLANT                   : DIOXIN SITE #11
        PLANT SITE              :
        SAMPLING LOCATION       : AMBIENT BY INCINERATOR
        TEST #                  : 11-AMB-A
        DATE                    : 8/6-8/85
        TEST PERIOD             :
(0925-1532)  (0840-1600)  (0845-1120/1145-1522)


      PARAMETER                                    VALUE
      ---------                                    -----

      Sampling time (min.)                          1179
      Barometric Pressure (in.Hg)                   29.2
      Sampling nozzle diameter (in.)
      Meter Volume (cu.ft.)                         523.4001
      Meter Pressure (in.H2O)                       .36
      Meter Temperature (F)                         107.3
      Stack dimension (sq.in.)
      Stack Static Pressure (in.H2O)
      Stack Moisture Collected (gm)                 162.4
      Absolute stack pressure(in Hg)
      Average stack temperature (F)                 90
      Percent CO2                                   .001
      Percent O2                                    21
      Percent N2                                    79
      Delps Subroutine result
      DGM Factor                                    1.002
      Pitot Constant
```

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```
        RADIAN SOURCE TEST
        EPA METHODS 2-5
        FINAL RESULTS
      PLANT                  : DIOXIN SITE #11
      PLANT SITE             :
      SAMPLING LOCATION      : AMBIENT BY INCINERATOR
      TEST #                 : 11-AMB-B
      DATE                   : 8/6-8/85
      TEST PERIOD            :
(0925-1532)  (0840-1602)  (0845-1120/1145-1522)


        PARAMETER                   RESULT
        ---------                   ------

        Vm(dscf)                     498.1945
        Vm(dscm)                     14.10887
        Vw gas(scf)                  8.28897
        Vw gas (scm)                 .2347436
        % moisture                   1.636573
        Md                           .9836342
        MWd                          28.84044
        MW                           28.66303








                                                 Program Revision:1/16/8-
```

APPENDIX B

PROCESS MONITORING DATA

TABLE B-1. OPERATING DATA, RUN 1

	Time	AFTER-BURNER TEMP. °F	FURNACE TEMP °F	DRUM COUNT	AFTERBURNER GAS USAGE	
					TIME	METER READING (cu.ft.)
START	9:30	NR	NR	0	9:30	0362500 cu.ft.
	9:32	1600	NR	30	9:48	0364700 cu.ft.
	9:45	1580	NR	53	10:05	0366780 cu.ft.
	10:00	1570	NR	92	10:21	0368610 cu.ft.
	10:15	1590	NR	130	11:03	0372780 cu.ft.
	10:30	1580	NR	164		
	10:45	1590	NR	193		
	11:00	1590	1280	222		
	11:15	1590	NR	249		
STOP	11:30	1580	1220	266		
START	13:30			0		
	14:00	1590	1140	39	14:01	0393480 cu.ft.
	14:15	1590	1300	65	14:26	0396330 cu.ft.
	14:30	1590	1100	89	15:02	0400010 cu.ft.
	14:45	1580	1200	142	15:33	0403760 cu.ft.
	15:00	1570	1100	174		
	15:15	1410	1040	191		
STOP	15:30	1340	1000	191		

NR = Not recorded

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TABLE B-2. OPERATING DATA, RUN 2

	Time	AFTER-BURNER TEMP. °F	FURNACE TEMP °F	DRUM COUNT	AFTERBURNER GAS USAGE	
					TIME	METER READING (cu.ft.)
START	9:30	1480	1000			
	9:35		NR	0		
	9:45	1480	1100	32	9:54	0429180 cu.ft.
	10:00	1530	970	53	10:17	0432980 cu.ft.
	10:15	1580	NR	95	10:47	0435190 cu.ft.
	10:30	1570	920	129	11:17	0439050 cu.ft.
	10:45	1590	1100	170		
	11:00	1480	1200	200		
	11:15	1480	1300	239	13:47	0456920 cu.ft.
STOP	11:25			264	14:01	0458730 cu.ft.
	11:30	1570			14:18	0460800 cu.ft.
					14:31	0462260 cu.ft.
					15:02	0465890 cu.ft.
START	13:20	1500	980			
	13:29			0		
	13:30	1510	1140	5		
	13:45	1600		34		
	14:00	1250	930	44		
STOP	14:16	1020	820	44		
START	14:30	1160	805	51		
	14:45	1560	1160	88		
	15:00	1580	1010	120		
	15:15	1590	1040	154		
	15:30	1590	1020	192		

NR = Not recorded

TABLE B-3. OPERATING DATA, RUN 3

	Time	AFTER-BURNER TEMP. F	FURNACE TEMP F	DRUM COUNT	AFTERBURNER GAS USAGE	
					TIME	METER READING (cu.ft.)
START	9:00	1470	780			
	9:15	1540	820	0		
	9:30	1580	1000	48	9:32	04928800 cu.ft.
	9:45	1580	1140	86	10:02	04958000 cu.ft.
	10:00	1480	NR	109		
	10:15	1610	1240	155	10:19	04971100 cu.ft.
	10:30	1600	NR	196		
STOP	11:00	1590	1120	243		
START	13:15			0		
	13:30	1440	1180	37	13:34	05221200 cu.ft.
	13:45	1500	1260	68		
	14:00	1460	1020	79	14:01	05254600 cu.ft.
	14:15	1510	1160	123		
	14:30	1520	NR	151	14:32	05292500 cu.ft.
	14:45	1490	NR	182		
STOP	15:00	1540	1200	222	15:06	05335300 cu.ft.

NR = Not recorded

TABLE B-4. DRUM SAMPLING LOG, RUN 1

DRUM SAMPLE LOG

TIGHT HEAD DRUMS (DEHEADED)

No.	Description	Approximate Contents	Label	Comments
0	clear liquid	2"	alcohol NOS	
10	red liquid	10 cc	spray cologne	
20	blue liquid	100 cc	alcohol NOS	
30	clear liquid	50 cc	no label	
40	clear liquid	1/2"	tufflo 600c	
50	---	none	1,1,1 TCE	
60	pink liquid	1/2"	lacquer base paint	
70	pink liquid	100 cc	lacquer base paint	
80	clear liquid	100 cc	perfume oil	ash sample
90	clear liquid	200 cc	propylene glycol	bulk sample
100	clear liquid	200 cc	triethanolamine 85%	0950
110	clear liquid	1/2"	toluene E	
120	pink solid	none free	lacquer base paint	
130	clear liquid	1 gallon	tufflo 600c	
140	clear liquid	500 cc	isopropyl alcohol	
150	clear liquid	500 cc	1,2,4 TCB	
160	clear liquid (oily)	1000 cc	85% triethanolamine	
170	clear liquid	50 cc	methanol	
180	clear liquid	200 cc	MEK	
190	empty	dry	70% MEK 30% Toluene	
200	blue liquid	1/2"	TA lacquer	
210	blue liquid	1/2"	TA lacquer	
220	blue liquid	1/2"	TA lacquer	
230	blue liquid	1/2"	TA lacquer	
240	blue liquid	1/2"	TO lacquer	(different than TA)
250	blue liquid	1/2"	TA lacquer	
260	blue liquid	1/2"	TA lacquer	
				bulk sample
				ash 1110

Finish running tight heads at 1120.
Start open heads 1125.

TABLE B-4 (continued)

DRUM SAMPLE LOG

OPEN HEAD DRUMS

restart numbers 2nd port. restart 1330 hours

No.	Description	Approximate Contents	Label	Comments
0	clear sticky	1"	None	1330
10	empty		--	ash
20	green paint/ink	200 cc		
30	green ink	100 cc		nearly dried
40	green ink	1 liter	--	1335
50	purple ink	1/2"	--	dried
				1350-1405 feed stop
60	empty	clean		
70	ink powder	100 cc	very small amount solids	
80	ink	1 liter		1415
90	clean			
100	black powder	1/8"		
110	clean dry			
120	clean			
130	clean			ash
140	clean, thick	3/4"		1440
150	dark blue ink	2 gallons	strong odor	
160	dry			
170	pink ink	1 liter	Rhodamine	1455
180	clean thick	1/2"		
190	dry red ink/paint			1500 ash
200	dry orange paint			bulk
210	clean dry			stopped 1520-1540

end list 1530 hours.

TABLE B-5. DRUM SAMPLING LOG, RUN 2

Start feeding openheads @ 0815

Start Run 2: 0920 hours

No.	Description of Contents	Approximate Contents	Label	Comments
0	dry, clean	0 prior contents-juice	None	From yard storage
10	dry, clean	0		
20	dry, clean	prior contents-juice	citromato	
30	dry, clean	prior contents-juice	citromato	
40	dry, clean	prior contents-juice	citromato	0935 ash 9:47 stop open head
	begin tight heads			
41	---	TA Lacquer	---	begin 0950
50	blue liquid	2 gallons	Pt Lacquer	
60	white emulsion	2 liters	depanning compound	
70	white emulsion	1 gallon	depanning compound	
80	white emulsion	1 gallon	depanning compound	
90	clear liquid	1/2 liter	Bakewell k-machine oil	
100	no residue (free)		methanol	
110	clear liquid	1 gallon	methyl cellusolve	acetate (ethylene monomethyl ether acetate
120	blue liquid	1 liter	ML Lacquer	(MEK base)
130	blue liquid	1/2 liter	TO Lacquer	
140	blue liquid	1/2 liter (semi-dried)	TA Lacquer	(1035 ash)
150	clear liquid	1 gallon	MEK	
160	blue liquid	1/2 liter (semi-dried)	HG Lacquer	
170	brown liquid	1 liter	no label	1045 hrs.

TABLE B-5. DRUM SAMPLING LOG, RUN 2 (continued)

No.	Description of Contents	Approximate Contents	Label	Comments
180	dark liquid	1/2 liter	Isobutanol	break 1045-1050
190	blue paint	1/2 liter	Hq lacquer	
200	clear liquid	1/2 liter	AHCOWET-DQ114	(nonionic surfactant
210	clear liquid	100 cc	hexame	
220	clear liquid	100 cc	santicizer-120	
230	clear liquid	50 cc w/solids	(Butyl benzyl PHthalate)	
239	thick gel	1 liter	MONDUR CB 75	aromatic polyisocycm
240	blue paint	2 liters	ML Lacquer	
250	clear liquid	1/2 liter	methyl cellusolve	
260	blue paint	2 liters	Hq lacquer	
264	clear liquid	2 liters	Mark Stabilizer	(Barium/Cadmium /Zinc

TABLE B-5. DRUM SAMPLING LOG, RUN 2 (continued)

Start 2nd half of run 1320 hours
Start drum count/sampling 1325 hours

No.	Description of Contents	Approximate Contents	Label	Comments
0	red paint or ink	dry	none	lids isolated on most dry contents cannot sample
10	red paint or ink			
20	white ink			
30	red ink	sampled dry		
40	red ink	dry		
50	red ink			
		line stopped 1345-1425		(1345 ash)
60	white ink			
70	white ink			
80	black solid	dried ink	Adcote 335 M	
90	white ink			
100	Resin solvent		LAMOL 408-40	
110			LAMOL T-8	
120			LAMOL T-8	
130	Black ink			
140	unknown			
150	Blue ink			
160			LAMOL 408-40	
170			408-40	
180	ink			
190			LAMOL 408-40	
200			ADCOTE 35M	
			end test 2	1530 hours outlet 1535 inlet

200 last drum in

TABLE B-6. DRUM SAMPLING LOG, RUN 3

Burn open heads
Start run 0855. Drum count start delayed until start of paint drums: Did not sample to count - 50 juice drums in test at 0915

No.	Description of Contents	Approximate Contents	Label	Comments
0	paint	avg. contents 1/2 pt.	Polycron Bronze	high solids white interspersed -1 of 10 contents burn vigorously
10	paint		Polycron Bronze	
20	paint		Polycron Bronze	
30	paint		Polycron Bronze	
40	paint		Polycron Bronze	
50	paint		Polycron Bronze	
60	paint		Polycron Bronze	
70	paint		Polycron Bronze	
80	ink			
90	paint		Bronze	
100	paint		White Prolam	
110	orange ink			
120	unknown			
130	orange ink			1000 ash
140	paint			
150	paint			
160	wood filler			
180	paint			1030 ash
190	paint			
200	paint			
210	paint			
220	paint			
230	paint			
240	paint			1100 ash
250	paint			

TABLE B-6. DRUM SAMPLING LOG, RUN 3 (continued)

Start run 1315 hours
Tighthead drums

No.	Description of Contents	Approximate Contents	Label	Comments
0	---		no label	start lasso #2
10	white liquid	200 ml	LASSO	
20	white liquid in blue solid	50 ml	LASSO	
30	oily liquid	100 ml	LASSO	
40	ICONOL NP 4	500 ml	surfactant	39 end lasso
50	clear oily liquid	2 liters	ICONOL NP 4	
60	clear liquid	1 liter	MARK-4 stabilizer	ash 1335
70	clear liquid	1/2 liter	no label	these drums were labeled on lid is disposed of before sample station
80	brown oil	1 liter	no label	
90	clear liquid	50 cc	no label	
100	none	dry	no label	
110	dirty liquid	1/2 liter	no label	
120	dry	---	no label	ash 1410
130	dirty liquid	100 ml	no label	
140	dirty liquid	200 ml	no label	
150	dirty liquid	1 gallon	no label	
160	clear oily liquid	1/2 liter	no label	
170	clear oily liquid	100 cc	no label	
180	clean dry	---	no label	1435 ash
190	rusty surface by outline	50 cc	---	
200	milky emulsion	1 liter		
210	rusty			
220	dry clean			
230	dirty liquid			
	end tight head start paint (open head)			1505 ash
240	yellow pigment			
250	paint			
260	adhesive			end 259 1515 1515 ash

APPENDIX C

CEM DATA

Table C-1. CEM Data Corrected to 3% O_2, Run 1.

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**	FACTOR FOR 3% O2 NORMALIZATION OF OTHER PROCESS GASES	**	NORMALIZED / CORRECTED DATA - WITH ACTUAL O2 *						
**		**	TIME	O2 (%V)	CO (PPMV) @ 3% O2	CO2 (%V) @ 3% O2	SO2 (PPMV) @ 3% O2	NOX (PPMV) @ 3% O2	THC (PPMV) @ 3% O2
**	2.6500	**	920	14.1	114.7	12.2	15.5	125.9	2.6
**	2.0601	**	925	12.2	272.7	11.5	80.4	127.4	2.1
**	1.9822	**	930	11.9	270.3	11.1	136.2	127.0	2.2
**	2.3457	**	935	13.3	281.8	11.2	57.5	118.7	2.0
**	2.2060	**	940	12.8	216.8	11.2	53.2	112.4	1.9
**	2.2290	**	945	12.9	335.6	11.0	42.8	111.4	2.1
**	2.4999	**	950	13.7	205.2	10.9	26.2	108.9	2.3
**	2.2754	**	955	13.0	170.4	11.0	21.7	117.7	2.2
**	2.2639	**	1000	13.0	169.1	11.2	11.2	109.7	2.1
**	2.4670	**	1005	13.6	175.1	11.0	22.1	134.5	2.3
**	2.1009	**	1010	12.7	140.4	11.2	20.7	123.0	2.1
**	2.2531	**	1015	13.0	119.2	11.1	19.7	127.3	2.1
**	2.1402	**	1020	12.6	153.7	11.1	26.0	133.9	1.9
**	2.3162	**	1025	13.2	70.2	11.1	28.7	116.2	2.1
**	2.1241	**	1030	12.5	184.7	11.7	52.0	118.1	3.3
**	2.0095	**	1035	12.3	150.9	11.5	40.7	127.8	6.6
**	2.3407	**	1040	13.3	182.1	11.7	16.3	118.9	4.1
**	2.2261	**	1045	12.9	94.8	11.4	12.2	108.8	5.0
**	2.6001	**	1050	14.0	395.3	11.2	7.0	105.5	5.5
**	2.2533	**	1055	13.0	172.1	12.3	5.4	101.1	3.5
**	2.0705	**	1100	12.3	211.6	12.0	16.5	92.8	4.2
**	2.0765	**	1105	12.3	316.9	11.3	13.6	89.5	4.4
**	2.6691	**	1110	14.2	378.1	11.6	3.8	109.9	3.6
**	1.9710	**	1115	11.8	289.4	12.2	13.1	91.3	4.6
**	2.3927	**	1120	13.4	285.2	13.6	6.8	95.1	4.4
**	2.4254	**	1125	13.5	239.3	11.3	6.9	108.1	3.8
**	2.6186	**	1130	14.1	222.0	11.1		118.2	3.1
**	2.4184	**	1135	13.5	264.5	11.1	4.9	117.4	2.9
**	2.4340	**	1140	13.5	291.1	11.3	6.6	116.8	2.3
**	2.4821	**	1145	13.7	162.7	11.7	0.5	113.3	2.2
**	2.3784	**	1150	13.3	334.9	11.6	13.3	120.4	3.2
**	2.3136	**	1155	13.2	255.0	11.7	14.0	110.7	2.2
**	2.3956	**	1310	13.4	123.8	11.7		126.8	
**	2.1321	**	1315	12.5	95.4	11.4		138.9	
**	2.4222	**	1320	13.5		12.4		153.8	
**	2.2041	**	1325	12.8	75.9	11.6		172.3	0.4
**	2.1795	**	1330	12.7	94.6	11.6		158.1	0.7
**	3.5182	**	1335	15.8	786.6	9.9		158.0	1.7
**	3.5807	**	1340	15.9	530.5	12.1		145.5	3.2
**	1.9421	**	1345	11.7	334.9	12.0	1.1	176.5	0.6
**	2.3117	**	1350	13.2	242.8	12.8		180.7	0.7
**	2.2092	**	1355	12.8	184.8	11.9	4.4	178.2	1.0
**	2.9299	**	1400	14.8	583.6	10.8		156.5	1.2
**	2.3528	**	1405	13.3	445.7	13.1		168.5	1.3
**	2.1674	**	1410	12.6	166.4	12.4	12.3	184.9	0.9
**	2.2988	**	1415	13.1	238.4	12.1		154.4	0.8
**	2.5288	**	1420	13.8	310.8	13.0		156.9	1.3
**	2.2031	**	1425	13.1	432.9	12.2	3.1	182.5	1.1
**	2.2645	**	1430	13.0	418.3	12.2	5.4	179.4	1.4
**	2.2327	**	1435	12.9	375.6	13.0	9.4	169.8	1.6
CEMS DATA - SITE 11 - TEST 1									
**	2.3791	**	1440	13.4	339.9	12.0		142.4	1.8
**	2.4697	**	1445	13.7	328.9	11.8		143.9	1.6
**	2.3682	**	1450	13.3	188.1	12.5		156.7	2.0
**	2.3299	**	1455	13.2	502.4	12.3	0.9	139.8	1.8
**	2.4354	**	1500	13.6	224.8	12.2		146.5	2.0
NO. PTS.	55		NO. PTS.	55	54	55	38	55	52
MEAN	2.3577		MEAN	13.2	261.9	11.7	21.9	133.3	2.4
STD. DEV.	0.3		STD. DEV.	0.8	137.4	0.7	25.9	26.1	1.3

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Table C-2. CEM Data Corrected to 3% O_2, Run 2.

NORMALIZED / CORRECTED DATA - WITH ACTUAL O2 *

TIME	O2 (%V)	CO (PPMV) @ 3% O2	CO2 (%V) @ 3% O2	SO2 (PPMV) @ 3% O2	NOX (PPMV) @ 3% O2	THC (PPMV) @ 3% O2
910	13.2	374.5	11.2		119.5	3.6
915	13.6	301.6	10.9		124.5	2.9
920	14.2	343.0	11.3		123.3	2.9
925	13.8	361.8	10.9		123.1	2.3
930	13.7	298.4	11.1		114.8	1.9
935	14.2	272.8	11.6		127.0	2.2
940	13.9	185.2	10.9		129.3	3.5
945	13.9	330.2	11.0		122.1	2.0
950	13.2	207.9	11.0		102.0	1.8
955	14.0	208.4	11.3		109.9	2.0
1000	12.3	95.7	11.8		116.2	1.5
1005	14.4	159.1	10.5		109.7	2.0
1010	13.0	95.9	11.5		111.3	1.7
1015	12.2	105.1	12.1		103.0	1.5
1020	12.6	81.0	12.2	52.9	106.1	1.7
1025	14.0	35.2	11.0		107.9	1.9
1030	11.9	58.0	13.0	46.1	115.5	1.6
1035	13.8	236.2	13.9	14.1	124.7	2.0
1040	13.0	49.2	12.2	4.7	121.2	1.7
1045	15.6	444.2	10.9		125.8	7.3
1050	14.6		11.8		131.2	2.2
1055	13.9	77.7	11.7		119.5	2.1
1100	13.7	56.5	11.9		108.9	1.6
1105	14.5	243.4	11.2		110.4	2.1
1110	14.2	213.1	11.9		115.0	2.4
1115	12.8		12.5		140.5	2.0
1120	12.7	278.0	12.6		105.3	1.9
1125	13.4	54.5	12.1		109.5	2.3
1130	14.4	182.1	11.5		122.0	2.8
1135	16.0	520.4	11.4		112.5	7.6
1140	13.3	248.8	12.3		112.0	2.7
1145	12.8	79.3	12.3		107.7	2.5
1150	13.9	166.4	11.4		101.5	3.1
1155	13.9	176.5	11.7		95.8	3.0
1200	14.4	311.3	11.0		91.4	3.0
1255	14.7	666.1	11.5		106.4	2.2
1300	14.8	772.9	10.7		85.4	1.2
1305	15.1	497.9	11.9		93.6	0.4
1310	13.4	247.0	12.2		126.0	0.4
1315	13.2	304.8	12.1	4.3	143.4	0.7
1320	13.5	337.9	12.1		165.1	1.0
1325	13.1	331.8	12.4		146.5	1.0
1330	11.2	317.3	12.5	6.4	163.3	0.9
1335	13.5	268.6	13.3		157.9	0.7
1340	12.7		12.2		169.2	1.0
1345	14.0	109.8	10.9		165.0	1.4
1350	17.2	582.9	11.6		119.0	30.0
1355	17.3	793.8	12.3		103.9	43.1
1400	17.3	479.9	11.9		95.7	51.3
1405	17.4	912.9	12.1		92.2	49.7
1410	17.4	779.0	11.9		88.4	46.6
1415	17.7	583.6	10.9		86.3	70.3
1420	16.0	264.0	13.8		169.2	33.1
1425	13.7	106.1	12.4		171.6	2.7
1430	12.5	92.0	12.1		174.7	2.6
1435	11.7		13.5		161.7	7.7
1440	13.0		11.8		157.6	1.8
1445	12.9	21.8	11.8		194.2	9.1
1450	12.7	8.7	13.8		207.1	8.9
1455	13.1		12.4		171.5	9.3
1500	13.3	82.8	11.7		166.6	9.4
1505	13.4	245.2	12.9		184.1	3.9
1510	12.5	157.4	12.9		200.3	8.5
1515	13.1	81.4	12.3		188.5	2.1
1520	12.7	50.2	13.0		182.5	1.5
0	13.1	32.2	12.6		186.5	1.6
0	13.4	268.5	11.6		156.5	2.0
NO. PTS.	67	61	67	6	67	67
MEAN	13.9	266.4	11.9	21.4	131.3	7.5
STD. DEV.	1.4	209.8	0.8	20.2	31.6	14.1

Table C-3. CEM Data Corrected to 3% O_2, Run 3.

**	FACTOR FOR 3% O2 NORMALIZATION OF OTHER PROCESS GASES	**	NORMALIZED / CORRECTED DATA - WITH ACTUAL O2 *						
**		**	TIME	O2 (%V)	CO (PPMV) @ 3% O2	CO2 (%V) @ 3% O2	SO2 (PPMV) @ 3% O2	NOX (PPMV) @ 3% O2	THC (PPMV) @ 3% O2
**	1.8527	**	920	11.2	124.2	11.8	24.1	190.5	0.9
**	1.8877	**	925	11.4	95.7	12.6	22.5	176.6	1.1
**	2.4385	**	930	13.6	286.5	11.1	15.6	74.5	1.7
**	2.0497	**	935	12.2	144.8	13.3	15.7	115.4	1.5
**	1.8568	**	940	11.3	108.0	12.4	19.6	96.3	1.3
**	2.3340	**	945	13.2	269.3	10.8	23.6	77.8	1.4
**	2.0297	**	950	12.1	121.2	12.5	11.3	93.1	1.4
**	3.1844	**	955	15.3	409.9	11.2		139.7	2.2
**	1.8958	**	1000	11.5	114.0	12.0	2.7	169.0	1.0
**	2.0097	**	1005	12.0	131.8	12.2	8.3	191.0	1.2
**	1.9515	**	1010	11.7	185.7	12.5	12.3	201.9	0.8
**	1.9342	**	1015	11.6	69.8	11.7	12.8	197.2	0.7
**	2.2214	**	1020	12.8	217.5	13.0	20.9	189.3	1.3
**	2.0337	**	1045	12.1	247.2	12.3	7.1	177.4	1.2
**	2.3697	**	1050	13.3	253.3	13.0	3.8	163.0	1.4
**	2.2726	**	1055	13.0	343.6	11.6	6.4	166.0	1.1
**	3.8754	**	1100	16.3	665.1	10.2		205.3	2.9
**	2.7496	**	1320	14.4	3.1	11.8		100.6	3.7
**	2.5010	**	1325	13.7		11.5		124.9	5.0
**	2.6569	**	1330	14.2		11.5		131.4	1.8
**	2.8575	**	1335	14.6		11.4		130.4	1.3
**	2.4650	**	1340	13.6		11.8	23.1	114.2	1.2
**	2.5450	**	1345	13.9		10.8	0.6	111.5	0.8
**	3.8384	**	1350	16.2	263.4	11.4		114.7	60.0
**	2.6799	**	1355	14.2	31.9	11.7		105.0	76.0
**	2.4982	**	1400	13.7		11.9		109.9	71.2
**	2.5269	**	1405	13.8		11.6		103.1	1.9
**	2.5364	**	1410	13.8		11.8		88.1	1.2
**	2.7710	**	1415	14.4		11.5		90.2	1.1
**	2.5884	**	1420	14.0	19.7	11.5		97.9	0.8
**	2.6838	**	1425	14.2	203.6	11.2		89.6	1.1
**	2.7238	**	1430	14.3	306.1	11.4		90.3	3.5
**	2.6986	**	1435	14.3	32.9	11.0		98.2	5.9
**	2.6583	**	1440	14.2	53.7	11.8		99.8	5.3
**	2.8747	**	1445	14.7		12.4		92.5	1.2
**	2.3987	**	1450	13.4		11.7		112.1	0.8
**	2.6074	**	1455	14.0		11.1		117.9	1.0
**	2.5737	**	1500	13.9		11.7		136.7	0.7
**	2.0586	**	1505	12.2	34.5	12.5	9.0	163.1	0.7
**	2.2872	**	1510	13.1	35.1	12.9	19.8	185.6	0.8
**	2.1785	**	1515	12.7	127.2	12.5	1.7	138.0	1.2
NO. PTS.	41		NO. PTS.	41	28	41	28	41	41
MEAN	2.4672		MEAN	13.4	175.0	11.8	13.4	131.0	6.8
STD. DEV.	0.5		STD. DEV.	1.2	142.5	0.7	8.3	39.0	18.4

* CO, CO2, SO2, NOx and THC values are corredcted to 3% O2. To obtain actual measured values, divide values in the table by the corresponding normalization factor.

APPENDIX D

SAMPLE SHIPPING LETTERS

August 8, 1985

U.S. EPA ECC Toxicant Analysis Center
Building 1105
Bay St. Louis, MS 39529

Attention: Danny McDaniel

Subject: Tier 4 - Analysis Instructions

Dear Sir:

The objective of this letter is to clarify instructions and priorities f individual samples from specific Tier 4 combustion sites. This instruction letter is No. 15 and pertains to EPA Site No. 11.

The Episode No. is 2672, and SCC numbers assigned to this site were numb DQ002900 through DQ002999.

SCC numbers DQ002901 through DQ002906 have been assigned to Troika for internal QA/QC purposes. SCC numbers DQ002907 through DQ002930 have been assigned to samples included in this shipment. DQ002931 and DQ002932 have been assigned to the bioassay samples sent to EPA-Duluth. All remaining SCC numbers are unused.

The sample shipment for EPA Site No. 11 (DBR-A) consists of 6 boxes containing 66 samples. The boxes were shipped under Federal Express Airbill Nos. 770332732 and 082466473.

Instructions for extraction and analysis follow.

1. Priority #1 samples include the sample train components, the bottom ash, scrubber effluent samples, the lab proof blank, and the reagent blanks. These samples require immediate extraction and analysis.

MM5 TRAIN SAMPLES

Radian Run # 11-MM5-AO-01 (Total of 6 train components)

SCC No.	Container	Fraction
DQ002907	1	Filter
DQ002907	2	Probe Rinse
DQ002907	3	Back Half/Coil Rinse
DQ002907	4	Condensate
DQ002907	5	Impinger Solution
DQ002907	6	XAD Module

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Radian Run # 11-MM5-AI-01 (Total of 6 train components)

SCC No.	Container	Fraction
DQ002908	1	Filter
DQ002908	2	Probe Rinse
DQ002908	3	Back Half/Coil Rinse
DQ002908	4	Condensate
DQ002908	5	Impinger Solution
DQ002908	6	XAD Module

Radian Run # 11-MM5-AO-02 (Total of 6 train components)

SCC No.	Container	Fraction
DQ002922	1	Filter
DQ002922	2	Probe Rinse
DQ002922	3	Back Half/Coil Rinse
DQ002922	4	Condensate
DQ002922	5	Impinger Solution
DQ002922	6	XAD Module

Radian Run # 11-MM5-AI-02 (Total of 6 train components)

SCC No.	Container	Fraction
DQ002920	1	Filter
DQ002920	2	Probe Rinse
DQ002920	3	Back Half/Coil Rinse
DQ002920	4	Condensate
DQ002920	5	Impinger Solution
DQ002920	6	XAD Module

Radian Run # 11-MM5-AO-03 (Total of 6 train components)

SCC No.	Container	Fraction
DQ002919	1	Filter
DQ002919	2	Probe Rinse
DQ002919	3	Back Half/Coil Rinse
DQ002919	4	Condensate
DQ002919	5	Impinger Solution
DQ002919	6	XAD Module

Radian Run # 11-MM5-AI-03 (Total of 6 train components)

DQ002926	1	Filter
DQ002926	2	Probe Rinse
DQ002926	3	Back Half/Coil Rinse
DQ002926	4	Condensate
DQ002926	5	Impinger Solution
DQ002926	6	XAD Module

FIELD BLANKS

Radian Run # 11-MM5-AO-BL

DQ002924	1	Filter
DQ002924	2	Probe Rinse
DQ002924	3	Back Half/Coil Rinse
DQ002924	4	Condensate
DQ002924	5	Impinger Solution
DQ002924	6	XAD Module

Radian Run # 11-MM5-AI-BL

DQ002925	1	Filter
DQ002925	2	Probe Rinse
DQ002925	3	Back Half/Coil Rinse
DQ002925	4	Condensate
DQ002925	5	Impinger Solution
DQ002925	6	XAD Module

AMBIENT TRAIN

Radian Run # 11-AMB-A (Total of 2 train components)

SCC No.	Container	Fraction
DQ002917	1	XAD Module
DQ002917	2	Probe Rinse

LABORATORY PROOF BLANK

Radian Sample Code: 11-MM5-LAB/PR

SCC No.	Container	Fraction
DQ002913	1	Filter
DQ002913	2	Probe Rinse, Back Half/Coil Rinse and Impinger Soln.
DQ002913	3	XAD Module

REAGENT BLANKS

Radian Sample Code: 11-RBL

SCC No.	Sample
DQ002914	HPLC grade water blank
DQ002915	Acetone blank
DQ002916	Methylene chloride blank

FURNACE INLET BOTTOM ASH - PROCESS SAMPLE

Radian Sample Code: 11-FIA

SCC No.	Sample
DQ002911	Ash, Run 01
DQ002923	Ash, Run 02
DQ002927	Ash, Run 03

FURNACE OUTLET BOTTOM ASH - PROCESS SAMPLE

Radian Sample Code: 11-FOA

SCC No.	Sample
DQ002912	Ash, Run 01
DQ002921	Ash, Run 02
DQ002928	Ash, Run 03

2. The Drum Residues and drum coatings are Priority #2 samples. The sampl should be held at Troika pending the results of the Priority #1 samples

DRUM RESIDUES - PROCESS SAMPLE

Radian Sample Code: 11-DR-A

SCC No.	Sample
DQ002909	Drum residues, Run 01
DQ002918	Drum residues, Run 02
DQ002929	Drum residues, Run 03

DRUM COATINGS- PROCESS SAMPLE

Radian Sample Code: 11-DC-A

SCC No.	Sample
DQ002910	Drum residues, one sample for entire test

3. The soil sample is a Priotity #3 sample. This sample will be held at Radian pending results or Priority #1 and Priority #2 analysis. The SC number for this sample is DQ002930 and the Radian sample code is 11-S.

If any questions arise concerning this sample shipment, please contact either Winton Kelly or Mike Hartman at Radian Corporation at (919) 541-9100.

Sincerely,

Winton Kelly
FIELD ENGINEER

cc: E. Hanks/EPA/AMTB
A. Miles/Radian
Radian Field File - RTP/PPK

August 8, 1985

Dr. Douglas Kuehl
EPA/ERL
6201 Congdon Blvd.
Duluth, Minnesota 55804

Dear Dr. Kuehl:

Enclosed are the ash samples you requested through William B. Kuykendal, EPA/OAQPS-RTP in his August 16, 1984 letter to Andrew J. Miles/Radian Corporation. The ash samples were collected at Site 11 as part of the emissions test being conducted under Tier 4 of the National Dioxin Study. Site 11 is a steel drum burning furnace with an afterburner emission control system.

The ash samples are 5 lb composites of furnace inlet and outlet bottom ash collected during the three test days. The ash was collected from the furnace inlet and outlet ash pits. The samples are labeled as follows:

FURNACE INLET BOTTOM ASH

Radian Run # 11-FIA
SCC # DQ002931
Sample description: 5 lb composite (1/3 collected test run) of furnace bottom ash.

FURNACE OUTLET BOTTOM ASH

Radian Run # 11-FOA
SCC # DQ002932
Sample description: 5 lb composite (1/3 collected test run) of furnace bottom ash.

The sample containers were prepared as detailed in the "National Dioxin Study Tier 4 - Combustion Sources, Quality Assurance Project Plan". The report is an appendix to the site specific test plan for Site 11 which has been enclosed to supply any additional information you may require concerning these samples.

If you have any questions concerning this sample shipment, please contact either Andrew Miles or Winton Kelly at Radian Corporation at (919) 541-9100.

Sincerely,

Winton Kelly
FIELD ENGINEER

cc: A. Miles/Radian
Radian Field File - RTP/PPK

August 8, 1985

Mr. Larry Mutschler
Radian Analytical Services
8501 Mo-Pac Blvd. (Loop 1)
P.O. Box 9948
Austin, Texas 78766

Dear Larry:

The purpose of this letter is to clarify analytical instructions for Tier 4 field samples shipped to Radian Analytical Services in Batch No. RAS-14. These samples are on Federal Express Airbill No. 082466484, shipped on August 8, 1985.

Batch No. RAS-14 consists of 22 samples. The samples are from a Drum and Barrel Reconditioning Furnace. Please analyze these samples for total chloride by ion chromatography. The drum coatings and drum residue samples (Field # 19, 41, 76, 79) will require Parr Bomb procedures prior to ion chromatography analysis. Please perform duplicate analysis on all samples as indicated by an asterisk in Table 1. The charge number for the analysis is 222-109-02-09.

If you have any questions regarding these analytical instructions, please call Mike Hartman at (919) 481-0212 or Winton Kelly at (919) 541-9100. Please advise on the expected analytical schedule as soon as possible by return mail.

Sincerely,

Winton Kelly
Field Engineer

JM/djb

cc: Field Files
Andrew Miles, Radian/RTP
Bill Kuykendal, EPA/AMTB
Mike Hartman, Radian/RTP
Jim McGaughey, Radian/PPK

Table 1. Sample Codes and Analytical Instructions for RAS-14 Sample Shipment

Sample Code	Field No.	Analytical Requirements
AUDIT SAMPLES		
11-RAS-CL-6*	CH-1	Analyze for total Chloride
11-RAS-CL-7*	CH-2	Analyze for total Chloride
11-RAS-CL-8*	CH-3	Analyze for total Chloride
11-RAS-CL-9*	CH-4	Analyze for total Chloride
11-RAS-CL-10*	CH-5	Analyze for total Chloride
HCL TRAINS		
11-HCl-01-F	CH-32	Analyze for total Chloride
11-HCl-01-PR	CH-33	Analyze for total Chloride
11-HCl-01-IR	CH-34	Analyze for total Chloride
11-HCL-02-F	CH-54	Analyze for total Chloride
11-HCL-02-PR	CH-55	Analyse for total Chloride
11-HCL-02-IR	CH-56	Analyze for total Chloride
11-HCL-03-F	CH-80	Analyze for total Chloride
11-HCL-03-PR	CH-81	Analyze for total Chloride
11-HCL-03-IR	CH-82	Analyze for total Chloride
PROCESS SAMPLES		
Drum Coatings		
11-DC-C	CH-76	Analyze for total Chloride
Drum Residues		
11-DR-01-C	CH-19	Analyze for total Chloride
11-DR-02-C	CH-41	Analyze for total Chloride
11-DR-03-C	CH-79	Analyze for total Chloride
REAGENT BLANKS		
NaOH Reagent Blank		
11-RBL-NaOH-A	CH-10	Analyze for total Chloride

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* Duplicate Analysis Requested

APPENDIX E

DIOXIN/FURAN ANALYTICAL DATA

TABLE E-1. DIOXIN/FURAN ANALYTICAL DATA FOR MM5 TRAINS AT THE AFTERBURNER INLET

Isomer/Homologue	Amount Detected Picograms Per Train Run 01	Run 02	Run 03
DIOXINS			
2378 TCDD	20400	13300	9500
Other TCDD	70500	45600	78600
Penta-CDD	106800	39700	118800
Hexa-CDD	103800	25800	204900
Hepta-CDD	583800	10700	203100
Octa-CDD	216900	9000	44400
TOTAL CDD	1102200	144100	659300
FURANS			
2378 TCDF	59100	50500	48200
Other TCDF	796100	500900	1018300
Penta-CDF	691600	254250	638100
Hexa-CDF	177800	46800	349600
Hepta-CDF	541600	19500	198000
Octa-CDF	174500	4500	46800
TOTAL CDF	2440700	876450	3966281

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TABLE E-2. DIOXIN/FURAN ANALYTICAL DATA FOR MM5 TRAINS AT THE AFTERBURNER OUTLET

Isomer/Homologue	Amount Detected Picograms Per Train		
	Run 01	Run 02	Run 03
DIOXINS			
2378 TCDD	100	40	100
Other TCDD	2400	1260	1800
Penta-CDD	2200	400	700
Hexa-CDD	2000	600	1050
Hepta-CDD	3600	1100	1300
Octa-CDD	2000	1100	1100
TOTAL PCDD	12300	4500	6050
FURANS			
2378 TCDF	2400	800	900
Other TCDF	25300	21650	18400
Penta-CDD	14900	6500	6950
Hexa-CDD	7400	3200	3050
Hepta-CDD	5100	2100	2000
Octa-CDD	1400	600	500
TOTAL PCDD	56500	34850	31800

APPENDIX F

RUN-SPECIFIC DIOXIN/FURAN EMISSIONS DATA

APPENDIX F-1

FURNACE OUTLET EXHAUST DUCT RUN-SPECIFIC DIOXIN/FURAN EMISSIONS DATA
(As-measured concentrations)

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TABLE F-1. FURNACE OUTLET DIOXIN/FURAN EMISSIONS DATA FOR RUN 1, SITE DBR-A (As-measured Concentrations)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	4.98E+00(N/A)	3.72E-01(N/A)	3.34E+01
Other TCDD	1.72E+01(N/A)	1.28E+00(N/A)	1.15E+02
Penta-CDD	2.60E+01(N/A)	1.76E+00(N/A)	1.75E+02
Hexa-CDD	2.53E+01(N/A)	1.56E+00(N/A)	1.70E+02
Hepta-CDD	1.42E+02(N/A)	8.06E+00(N/A)	9.56E+02
Octa-CDD	5.29E+01(N/A)	2.77E+00(N/A)	3.55E+02
Total PCDD	2.69E+02	1.58E+01	1.80E+03
FURANS			
2378 TCDF	1.44E+01(N/A)	1.13E+00(N/A)	9.68E+01
Other TCDF	1.94E+02(N/A)	1.53E+01(N/A)	1.30E+03
Penta-CDF	1.69E+02(N/A)	1.19E+01(N/A)	1.13E+03
Hexa-CDF	4.34E+01(N/A)	2.78E+00(N/A)	2.91E+02
Hepta-CDF	1.32E+02(N/A)	7.77E+00(N/A)	8.87E+02
Octa-CDF	4.26E+01(N/A)	2.31E+00(N/A)	2.86E+02
Total PCDF	5.95E+02	4.12E+01	4.00E+03

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

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TABLE F-2. FURNACE OUTLET DIOXIN/FURAN EMISSIONS DATA FOR RUN 2, SITE DBR-A (As-measured Concentrations)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	3.06E+00(N/A)	2.29E-01(N/A)	2.37E+01
Other TCDD	1.05E+01(N/A)	7.85E-01(N/A)	8.13E+01
Penta-CDD	9.15E+00(N/A)	6.18E-01(N/A)	7.07E+01
Hexa-CDD	5.94E+00(N/A)	3.66E-01(N/A)	4.60E+01
Hepta-CDD	2.47E+00(N/A)	1.40E-01(N/A)	1.91E+01
Octa-CDD	2.07E+00(N/A)	1.08E-01(N/A)	1.60E+01
Total PCDD	3.32E+01	2.25E+00	2.57E+02
FURANS			
2378 TCDF	1.16E+01(N/A)	9.15E-01(N/A)	9.00E+01
Other TCDF	1.15E+02(N/A)	9.07E+00(N/A)	8.93E+02
Penta-CDF	5.86E+01(N/A)	4.14E+00(N/A)	4.53E+02
Hexa-CDF	1.08E+01(N/A)	6.92E-01(N/A)	8.34E+01
Hepta-CDF	4.49E+00(N/A)	2.64E-01(N/A)	3.47E+01
Octa-CDF	1.04E+00(N/A)	5.62E-02(N/A)	8.02E+00
Total PCDF	2.02E+02	1.51E+01	1.56E+03

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

TABLE F-3. FURNACE OUTLET DIOXIN/FURAN EMISSIONS DATA FOR RUN 3, SITE DBR-A (As-measured Concentrations)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	2.49E+00(N/A)	1.86E-01(N/A)	1.56E+01
Other TCDD	2.06E+01(N/A)	1.54E+00(N/A)	1.29E+02
Penta-CDD	3.11E+01(N/A)	2.10E+00(N/A)	1.95E+02
Hexa-CDD	5.36E+01(N/A)	3.30E+00(N/A)	3.36E+02
Hepta-CDD	5.32E+01(N/A)	3.01E+00(N/A)	3.33E+02
Octa-CDD	1.16E+01(N/A)	6.08E-01(N/A)	7.29E+01
Total PCDD	1.73E+02	1.07E+01	1.08E+03
FURANS			
2378 TCDF	1.26E+01(N/A)	9.92E-01(N/A)	7.91E+01
Other TCDF	2.67E+02(N/A)	2.10E+01(N/A)	1.67E+03
Penta-CDF	1.67E+02(N/A)	1.18E+01(N/A)	1.05E+03
Hexa-CDF	9.15E+01(N/A)	5.87E+00(N/A)	5.74E+02
Hepta-CDF	5.18E+01(N/A)	3.05E+00(N/A)	3.25E+02
Octa-CDF	1.23E+01(N/A)	6.64E-01(N/A)	7.68E+01
Total PCDF	6.02E+02	4.34E+01	3.77E+03

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

APPENDIX F-2

AFTERBURNER OUTLET STACK RUN-SPECIFIC DIOXIN/FURAN EMISSIONS DATA

(As-measured concentrations)

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TABLE F-4. AFTERBURNER OUTLET STACK DIOXIN/FURAN EMISSIONS DATA FOR RUN 1, SITE DBR-A (As-measured Concentrations)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	2.86E-02(N/A)	2.13E-03(N/A)	3.09E-01
Other TCDD	6.86E-01(N/A)	5.12E-02(N/A)	7.41E+00
Penta-CDD	6.29E-01(N/A)	4.25E-02(N/A)	6.79E+00
Hexa-CDD	5.71E-01(N/A)	3.52E-02(N/A)	6.17E+00
Hepta-CDD	1.03E+00(N/A)	5.82E-02(N/A)	1.11E+01
Octa-CDD	5.71E-01(N/A)	2.99E-02(N/A)	6.17E+00
Total PCDD	3.51E+00	2.19E-01	3.80E+01
FURANS			
2378 TCDF	6.86E-01(N/A)	5.39E-02(N/A)	7.41E+00
Other TCDF	7.23E+00(N/A)	5.68E-01(N/A)	7.81E+01
Penta-CDF	4.26E+00(N/A)	3.01E-01(N/A)	4.60E+01
Hexa-CDF	2.11E+00(N/A)	1.36E-01(N/A)	2.28E+01
Hepta-CDF	1.46E+00(N/A)	8.57E-02(N/A)	1.57E+01
Octa-CDF	4.00E-01(N/A)	2.17E-02(N/A)	4.32E+00
Total PCDF	1.61E+01	1.17E+00	1.74E+02

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

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TABLE F-5. AFTERBURNER OUTLET STACK DIOXIN/FURAN EMISSIONS DATA FOR RUN 2, SITE DBR-A (As-measured Concentrations)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	1.10E-02(N/A)	8.23E-04(N/A)	1.30E-01
Other TCDD	3.47E-01(N/A)	2.59E-02(N/A)	4.10E+00
Penta-CDD	1.10E-01(N/A)	7.45E-03(N/A)	1.30E+00
Hexa-CDD	1.65E-01(N/A)	1.02E-02(N/A)	1.95E+00
Hepta-CDD	3.03E-01(N/A)	1.72E-02(N/A)	3.58E+00
Octa-CDD	3.03E-01(N/A)	1.58E-02(N/A)	3.58E+00
Total PCDD	1.24E+00	7.74E-02	1.46E+01
FURANS			
2378 TCDF	2.20E-01(N/A)	1.73E-02(N/A)	2.60E+00
Other TCDF	5.96E+00(N/A)	4.69E-01(N/A)	7.04E+01
Penta-CDF	1.79E+00(N/A)	1.27E-01(N/A)	2.11E+01
Hexa-CDF	8.82E-01(N/A)	5.66E-02(N/A)	1.04E+01
Hepta-CDF	5.79E-01(N/A)	3.40E-02(N/A)	6.83E+00
Octa-CDF	1.65E-01(N/A)	8.96E-03(N/A)	1.95E+00
Total PCDF	9.60E+00	7.12E-01	1.13E+02

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

TABLE F-6. AFTERBURNER OUTLET STACK DIOXIN/FURAN EMISSIONS DATA FOR RUN 3, SITE DBR-A (As-measured Concentrations)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Concentration In Flue Gas (ppt)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	2.58E-02(N/A)	1.93E-03(N/A)	3.11E-01
Other TCDD	4.64E-01(N/A)	3.47E-02(N/A)	5.59E+00
Penta-CDD	1.80E-01(N/A)	1.22E-02(N/A)	2.17E+00
Hexa-CDD	2.71E-01(N/A)	1.66E-02(N/A)	3.26E+00
Hepta-CDD	3.35E-01(N/A)	1.90E-02(N/A)	4.04E+00
Octa-CDD	2.84E-01(N/A)	1.48E-02(N/A)	3.42E+00
Total PCDD	1.56E+00	9.92E-02	1.88E+01
FURANS			
2378 TCDF	2.32E-01(N/A)	1.82E-02(N/A)	2.80E+00
Other TCDF	4.74E+00(N/A)	3.73E-01(N/A)	5.72E+01
Penta-CDF	1.79E+00(N/A)	1.27E-01(N/A)	2.16E+01
Hexa-CDF	7.86E-01(N/A)	5.04E-02(N/A)	9.48E+00
Hepta-CDF	5.15E-01(N/A)	3.03E-02(N/A)	6.21E+00
Octa-CDF	1.29E-01(N/A)	6.98E-03(N/A)	1.55E+00
Total PCDF	8.20E+00	6.06E-01	9.88E+01

NOTE: Isomer concentrations shown are at as-measured oxygen conditions.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

APPENDIX F-3

FURNACE OUTLET EXHAUST DUCT RUN-SPECIFIC DIOXIN/FURAN EMISSIONS DATA
(Concentrations Corrected to 3 Percent Oxygen)

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TABLE F-7. FURNACE OUTLET DIOXIN/FURAN EMISSIONS DATA FOR RUN 1, SITE DBR-A (Concentrations Corrected to 3 Percent Oxygen)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	1.76E+01(N/A)	1.31E+00(N/A)	3.34E+01
Other TCDD	6.07E+01(N/A)	4.53E+00(N/A)	1.15E+02
Penta-CDD	9.19E+01(N/A)	6.21E+00(N/A)	1.75E+02
Hexa-CDD	8.94E+01(N/A)	5.50E+00(N/A)	1.70E+02
Hepta-CDD	5.03E+02(N/A)	2.84E+01(N/A)	9.56E+02
Octa-CDD	1.87E+02(N/A)	9.76E+00(N/A)	3.55E+02
Total PCDD	9.49E+02	5.58E+01	1.80E+03
FURANS			
2378 TCDF	5.09E+01(N/A)	4.00E+00(N/A)	9.68E+01
Other TCDF	6.85E+02(N/A)	5.39E+01(N/A)	1.30E+03
Penta-CDF	5.95E+02(N/A)	4.21E+01(N/A)	1.13E+03
Hexa-CDF	1.53E+02(N/A)	9.82E+00(N/A)	2.91E+02
Hepta-CDF	4.66E+02(N/A)	2.74E+01(N/A)	8.87E+02
Octa-CDF	1.50E+02(N/A)	8.14E+00(N/A)	2.86E+02
Total PCDF	2.10E+03	1.45E+02	4.00E+03

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

TABLE F-8. FURNACE OUTLET DIOXIN/FURAN EMISSIONS DATA FOR RUN 2, SITE DBR-A (Concentrations Corrected to 3 Percent Oxygen)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	1.84E+01(N/A)	1.37E+00(N/A)	2.37E+01
Other TCDD	6.30E+01(N/A)	4.71E+00(N/A)	8.13E+01
Penta-CDD	5.49E+01(N/A)	3.71E+00(N/A)	7.07E+01
Hexa-CDD	3.57E+01(N/A)	2.19E+00(N/A)	4.60E+01
Hepta-CDD	1.48E+01(N/A)	8.37E-01(N/A)	1.91E+01
Octa-CDD	1.24E+01(N/A)	6.51E-01(N/A)	1.60E+01
Total PCDD	1.99E+02	1.35E+01	2.57E+02
FURANS			
2378 TCDF	6.98E+01(N/A)	5.49E+00(N/A)	9.00E+01
Other TCDF	6.92E+02(N/A)	5.44E+01(N/A)	8.93E+02
Penta-CDF	3.51E+02(N/A)	2.49E+01(N/A)	4.53E+02
Hexa-CDF	6.47E+01(N/A)	4.15E+00(N/A)	8.34E+01
Hepta-CDF	2.70E+01(N/A)	1.59E+00(N/A)	3.47E+01
Octa-CDF	6.22E+00(N/A)	3.37E-01(N/A)	8.02E+00
Total PCDF	1.21E+03	9.09E+01	1.56E+03

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

TABLE F-9. FURNACE OUTLET DIOXIN/FURAN EMISSIONS DATA FOR RUN 3, SITE DBR-A (Concentrations Corrected to 3 Percent Oxygen)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	1.32E+01(N/A)	9.84E-01(N/A)	1.56E+01
Other TCDD	1.09E+02(N/A)	8.14E+00(N/A)	1.29E+02
Penta-CDD	1.65E+02(N/A)	1.11E+01(N/A)	1.95E+02
Hexa-CDD	2.84E+02(N/A)	1.75E+01(N/A)	3.36E+02
Hepta-CDD	2.81E+02(N/A)	1.59E+01(N/A)	3.33E+02
Octa-CDD	6.15E+01(N/A)	3.22E+00(N/A)	7.29E+01
Total PCDD	9.14E+02	5.69E+01	1.08E+03
FURANS			
2378 TCDF	6.68E+01(N/A)	5.25E+00(N/A)	7.91E+01
Other TCDF	1.41E+03(N/A)	1.11E+02(N/A)	1.67E+03
Penta-CDF	8.84E+02(N/A)	6.26E+01(N/A)	1.05E+03
Hexa-CDF	4.85E+02(N/A)	3.11E+01(N/A)	5.74E+02
Hepta-CDF	2.74E+02(N/A)	1.61E+01(N/A)	3.25E+02
Octa-CDF	6.49E+01(N/A)	3.51E+00(N/A)	7.68E+01
Total PCDF	3.19E+03	2.30E+02	3.77E+03

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

APPENDIX F-4

AFTERBURNER OUTLET STACK RUN-SPECIFIC DIOXIN/FURAN EMISSIONS DATA
(Concentrations Corrected to 3 Percent Oxygen)

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TABLE F-10. AFTERBURNER OUTLET STACK DIOXIN/FURAN EMISSIONS DATA FOR RUN 1, SITE DBR-A (Concentrations Corrected to 3 Percent Oxygen)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	6.59E-02(N/A)	4.93E-03(N/A)	3.09E-01
Other TCDD	1.58E+00(N/A)	1.18E-01(N/A)	7.41E+00
Penta-CDD	1.45E+00(N/A)	9.80E-02(N/A)	6.79E+00
Hexa-CDD	1.32E+00(N/A)	8.11E-02(N/A)	6.17E+00
Hepta-CDD	2.37E+00(N/A)	1.34E-01(N/A)	1.11E+01
Octa-CDD	1.32E+00(N/A)	6.90E-02(N/A)	6.17E+00
Total PCDD	8.11E+00	5.06E-01	3.80E+01
FURANS			
2378 TCDF	1.58E+00(N/A)	1.24E-01(N/A)	7.41E+00
Other TCDF	1.67E+01(N/A)	1.31E+00(N/A)	7.81E+01
Penta-CDF	9.82E+00(N/A)	6.95E-01(N/A)	4.60E+01
Hexa-CDF	4.88E+00(N/A)	3.13E-01(N/A)	2.28E+01
Hepta-CDF	3.36E+00(N/A)	1.98E-01(N/A)	1.57E+01
Octa-CDF	9.23E-01(N/A)	5.00E-02(N/A)	4.32E+00
Total PCDF	3.73E+01	2.69E+00	1.74E+02

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

TABLE F-11. AFTERBURNER OUTLET STACK DIOXIN/FURAN EMISSIONS DATA FOR RUN 2, SITE DBR-A (Concentrations Corrected to 3 Percent Oxygen)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	2.79E-02(N/A)	2.09E-03(N/A)	1.30E-01
Other TCDD	8.80E-01(N/A)	6.57E-02(N/A)	4.10E+00
Penta-CDD	2.79E-01(N/A)	1.89E-02(N/A)	1.30E+00
Hexa-CDD	4.19E-01(N/A)	2.58E-02(N/A)	1.95E+00
Hepta-CDD	7.68E-01(N/A)	4.35E-02(N/A)	3.58E+00
Octa-CDD	7.68E-01(N/A)	4.02E-02(N/A)	3.58E+00
Total PCDD	3.14E+00	1.96E-01	1.46E+01
FURANS			
2378 TCDF	5.59E-01(N/A)	4.39E-02(N/A)	2.60E+00
Other TCDF	1.51E+01(N/A)	1.19E+00(N/A)	7.04E+01
Penta-CDF	4.54E+00(N/A)	3.21E-01(N/A)	2.11E+01
Hexa-CDF	2.23E+00(N/A)	1.43E-01(N/A)	1.04E+01
Hepta-CDF	1.47E+00(N/A)	8.63E-02(N/A)	6.83E+00
Octa-CDF	4.19E-01(N/A)	2.27E-02(N/A)	1.95E+00
Total PCDF	2.43E+01	1.81E+00	1.13E+02

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

TABLE F-12. AFTERBURNER OUTLET STACK DIOXIN/FURAN EMISSIONS DATA FOR RUN 3, SITE DBR-A (Concentrations Corrected to 3 Percent Oxygen)

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm @ 3% oxygen)	Isomer Concentration In Flue Gas (ppt @ 3% oxygen)	Isomer Hourly Emissions Rate (ug/hr)
DIOXINS			
2378 TCDD	6.10E-02(N/A)	4.56E-03(N/A)	3.11E-01
Other TCDD	1.10E+00(N/A)	8.21E-02(N/A)	5.59E+00
Penta-CDD	4.27E-01(N/A)	2.89E-02(N/A)	2.17E+00
Hexa-CDD	6.41E-01(N/A)	3.94E-02(N/A)	3.26E+00
Hepta-CDD	7.94E-01(N/A)	4.49E-02(N/A)	4.04E+00
Octa-CDD	6.71E-01(N/A)	3.51E-02(N/A)	3.42E+00
Total PCDD	3.69E+00	2.35E-01	1.88E+01
FURANS			
2378 TCDF	5.49E-01(N/A)	4.32E-02(N/A)	2.80E+00
Other TCDF	1.12E+01(N/A)	8.83E-01(N/A)	5.72E+01
Penta-CDF	4.24E+00(N/A)	3.00E-01(N/A)	2.16E+01
Hexa-CDF	1.86E+00(N/A)	1.19E-01(N/A)	9.48E+00
Hepta-CDF	1.22E+00(N/A)	7.18E-02(N/A)	6.21E+00
Octa-CDF	3.05E-01(N/A)	1.65E-02(N/A)	1.55E+00
Total PCDF	1.94E+01	1.43E+00	9.88E+01

NOTE: Isomer concentrations shown are corrected to 3% oxygen.

ND = not detected (detection limit in parentheses).
N/A = Not applicable when test values are positive. QA samples indicate method capabilities and minimum limits of detection.
ng = 1.0E-09g
ug = 1.0E-06g
ppt = parts per trillion, dry volume basis
1536 operating hours per year

APPENDIX G

RISK MODELING INPUT PARAMETERS (AFTERBURNER OUTLET)

TABLE G-1 . RISK MODELING PARAMETERS FOR RUN 1, SITE DBR-A

Stack Height (From Grade Level) = 11.3 m
Stack Diameter (ID) = 0.9 m
Flue Gas Flow Rate (Dry Standard) = 180.0 dscmm
Flue Gas Exit Temperature = 974.8 K
Flue Gas Exit Velocity (Actual) = 1023.44 mpm

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Hourly Emissions Rate (ug/hr)	Relative Potency Factor	2,3,7,8 - TCDD Equivalent Emissions (mg/yr)
2378 TCDD	2.86E-02	3.09E-01	1.000	4.74E-01
Other TCDD	6.86E-01	7.41E+00	.010	1.14E-01
2378 TCDF	6.86E-01	7.41E+00	.100	1.14E+00
Other TCDF	7.23E+00	7.81E+01	.001	1.20E-01
Penta-CDD	6.29E-01	6.79E+00	.500	5.21E+00
Penta-CDF	4.26E+00	4.60E+01	.100	7.06E+00
Hexa-CDD	5.71E-01	6.17E+00	.040	3.79E-01
Hexa-CDF	2.11E+00	2.28E+01	.010	3.51E-01
Hepta-CDD	1.03E+00	1.11E+01	.001	1.71E-02
Hepta-CDF	1.46E+00	1.57E+01	.001	2.42E-02
Octa-CDD	5.71E-01	6.17E+00	.000	.00E+00
Octa-CDF	4.00E-01	4.32E+00	.000	.00E+00
Net 2378 TCDD Equivalent Atmospheric Loading				1.49E+01

ND = not detected (detection limit in parentheses).
N/A = detection limit not available
ng = 1.0E-09g
ug = 1.0E-06g
mg = 1.0E-03g
Standard conditions: 293 K (20 C) temperature and 1 atmosphere pressure.
1536 operating hours per year

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TABLE G-2. RISK MODELING PARAMETERS FOR RUN 2, SITE DBR-A

Stack Height (From Grade Level) = 11.3 m
Stack Diameter (ID) = 0.9 m
Flue Gas Flow Rate (Dry Standard) = 196.7 dscmm
Flue Gas Exit Temperature = 946.3 K
Flue Gas Exit Velocity (Actual) = 1094.16 mpm

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Hourly Emissions Rate (ug/hr)	Relative Potency Factor	2,3,7,8 - TCDD Equivalent Emissions (mg/yr)
2378 TCDD	1.10E-02	1.30E-01	1.000	2.00E-01
Other TCDD	3.47E-01	4.10E+00	.010	6.29E-02
2378 TCDF	2.20E-01	2.60E+00	.100	4.00E-01
Other TCDF	5.96E+00	7.04E+01	.001	1.08E-01
Penta-CDD	1.10E-01	1.30E+00	.500	9.99E-01
Penta-CDF	1.79E+00	2.11E+01	.100	3.25E+00
Hexa-CDD	1.65E-01	1.95E+00	.040	1.20E-01
Hexa-CDF	8.82E-01	1.04E+01	.010	1.60E-01
Hepta-CDD	3.03E-01	3.58E+00	.001	5.49E-03
Hepta-CDF	5.79E-01	6.83E+00	.001	1.05E-02
Octa-CDD	3.03E-01	3.58E+00	.000	.00E+00
Octa-CDF	1.65E-01	1.95E+00	.000	.00E+00
Net 2378 TCDD Equivalent Atmospheric Loading				5.31E+00

ND = not detected (detection limit in parentheses).
N/A = detection limit not available
ng = 1.0E-09g
ug = 1.0E-06g
mg = 1.0E-03g
Standard conditions: 293 K (20 C) temperature and 1 atmosphere pressure.
1536 operating hours per year

TABLE G-3. RISK MODELING PARAMETERS FOR RUN 3, SITE DBR-A

Stack Height (From Grade Level) = 11.3 m
Stack Diameter (ID) = 0.9 m
Flue Gas Flow Rate (Dry Standard) = 200.9 dscmm
Flue Gas Exit Temperature = 950.2 K
Flue Gas Exit Velocity (Actual) = 1137.92 mpm

Dioxin/Furan Isomer	Isomer Concentration In Flue Gas (ng/dscm)	Isomer Hourly Emissions Rate (ug/hr)	Relative Potency Factor	2,3,7,8 - TCDD Equivalent Emissions (mg/yr)
2378 TCDD	2.58E-02	3.11E-01	1.000	4.77E-01
Other TCDD	4.64E-01	5.59E+00	.010	8.59E-02
2378 TCDF	2.32E-01	2.80E+00	.100	4.29E-01
Other TCDF	4.74E+00	5.72E+01	.001	8.78E-02
Penta-CDD	1.80E-01	2.17E+00	.500	1.67E+00
Penta-CDF	1.79E+00	2.16E+01	.100	3.32E+00
Hexa-CDD	2.71E-01	3.26E+00	.040	2.00E-01
Hexa-CDF	7.86E-01	9.48E+00	.010	1.46E-01
Hepta-CDD	3.35E-01	4.04E+00	.001	6.20E-03
Hepta-CDF	5.15E-01	6.21E+00	.001	9.54E-03
Octa-CDD	2.84E-01	3.42E+00	.000	.00E+00
Octa-CDF	1.29E-01	1.55E+00	.000	.00E+00
Net 2378 TCDD Equivalent Atmospheric Loading				6.43E+00

ND = not detected (detection limit in parentheses).
N/A = detection limit not available
ng = 1.0E-09g
ug = 1.0E-06g
mg = 1.0E-03g
Standard conditions: 293 K (20 C) temperature and 1 atmosphere pressure.
1536 operating hours per year

APPENDIX H
ERROR ANALYSIS: CONTROL DEVICE EFFICIENCY CALCULATIONS

Objective: Given the analytical uncertainty of the dioxin/furan analyses (± 50% accuracy), estimate the uncertainty of the control device efficiency calculations.

Let: $C_{out,meas}$ = the measured concentration of a given dioxin/furan homologue at the outlet location.

$C_{in,meas}$ = the measured concentration of a given dioxin/furan homologue at the inlet location.

$C_{out,max}$ = the maximum possible concentration of the dioxin/furan homologue given the measured value $C_{out,meas}$.

$C_{out,min}$ = the minimum possible concentration of the dioxin/furan homologue given the measured value $C_{out,meas}$.

$C_{in,max}$ = the maximum possible concentration of the dioxin/furan homologue, given the measured value $C_{in,meas}$.

$C_{in,min}$ = the minimum possible concentration of the dioxin/furan homologue, given the measured value $C_{in,meas}$.

E = the removal efficiency of the control device

Assuming ± 50 percent analytical accuracy:

$$C_{min} = C_{meas} - 0.5\ C_{meas} = 0.5\ C_{meas}$$

$$C_{max} = C_{meas} + 0.5\ C_{meas} = 1.5\ C_{meas}$$

Note that:

$$E_{max} = \frac{C_{in,max} - C_{out,min}}{C_{in,max}} = 1 - \frac{C_{out,min}}{C_{in,max}}$$

$$E_{max} = 1 - \frac{0.5\ C_{out,meas}}{1.5\ C_{in,meas}} = 1 - {}^{1}/_{3}\ (1 - E_{meas})$$

$$= {}^{2}/_{3} + {}^{1}/_{3}\ E_{meas}$$

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and:

$$E_{min} = \frac{C_{in,min} - C_{out,max}}{C_{in,min}} = 1 - \frac{C_{out,max}}{C_{in,min}}$$

$$= 1 - \frac{1.5\ C_{out,meas}}{0.5\ C_{in,meas}}$$

$$= 1 - 3\ (1 - E_{meas})$$

$$E_{min} = 3\ E_{meas} - 2$$

Now, $E_{min} > 0$ positive control (i.e., emissions reduction across the control device)

$$(3E_{meas} - 2) > 0$$

$$E_{meas} > {}^{2}/_{3}$$

Therefore, if E_{meas} is larger than 66.7 percent, the true removal efficiency can safely be assumed to be greater than zero.

And, $E_{max} < 0$ negative control (i.e., emissions increase across the control device)

$${}^{2}/_{3} + {}^{1}/_{3}\ E_{meas} < 0$$

$$E_{meas} < -2$$

Therefore, if E_{meas} is less than -200 percent, the true efficiency can safely be assumed to be less than zero.

To summarize:

$E_{meas} > 66.7$ percent	positive control
$-200 < E_{meas} < 66.7$ percent	no definitive conclusions can be drawn
$E_{meas} < 200$ percent	no negative control